ANNUAL ENVIRONMENTAL MONITORING REPORT

JANUARY–DECEMBER 1981

Rockwell International
Energy Systems Group
Rocky Flats Plant

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ANNUAL ENVIRONMENTAL MONITORING REPORT
U. S. DEPARTMENT OF ENERGY, ROCKY FLATS PLANT

January Through December 1981

ENVIRONMENTAL ANALYSIS

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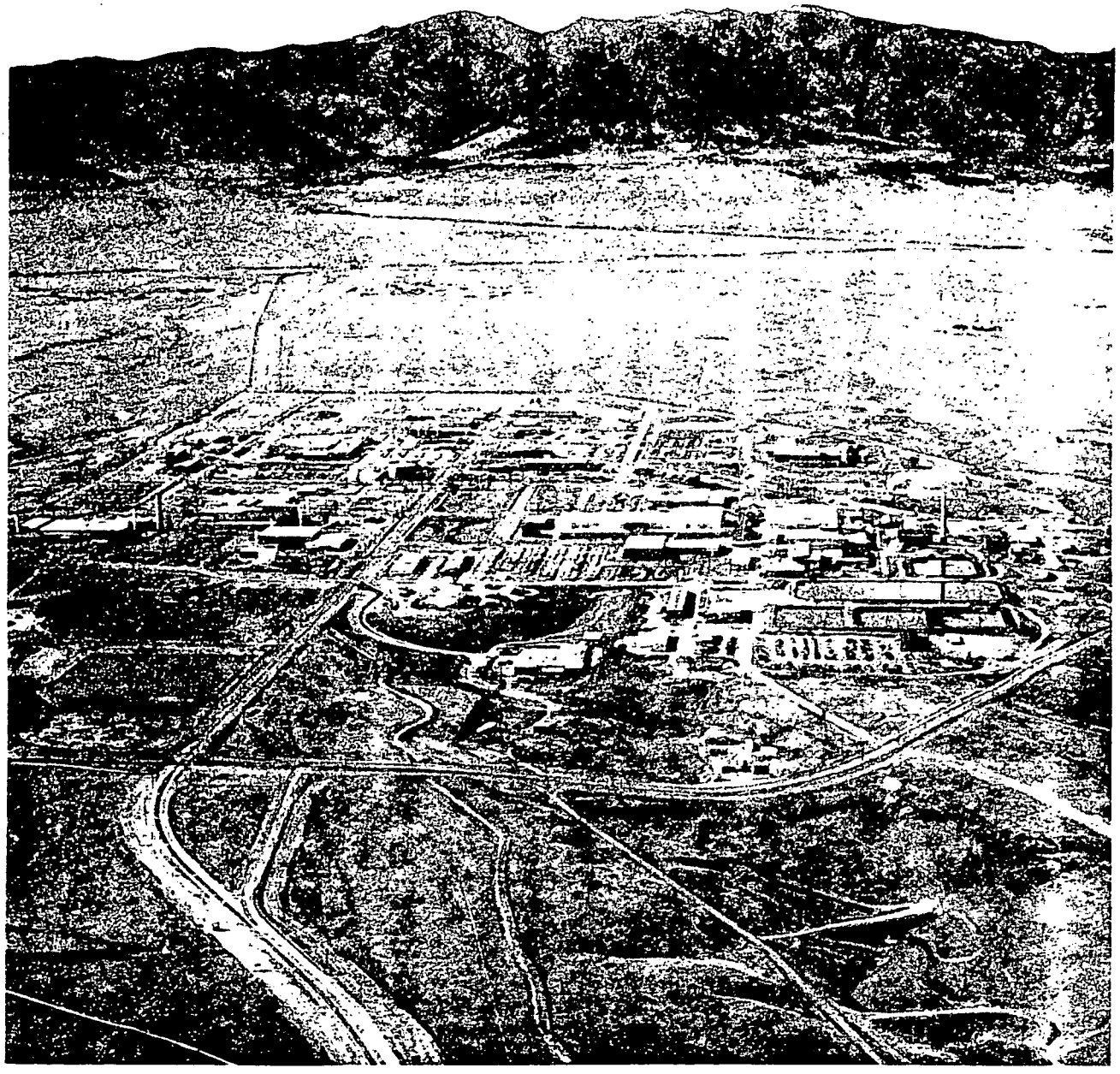

ROCKY FLATS PLANT VIEWED FROM THE EAST 24151-13A

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ABSTRACT

This report documents the 1981 environmental surveillance program at the Rocky Flats Plant, as conducted by the Environmental Analysis Section of the Environmental Sciences Branch. Sample analyses are performed by the Health, Safety and Environmental Laboratories of the Health, Safety and Environment Department and by the General Laboratory of the Quality Engineering and Control Department. This report includes an evaluation of Plant compliance with all appropriate guides, limits, and standards. Potential public radiation dose commitments were calculated from average radionuclide concentrations measured at the Plant property boundaries and in surrounding communities. Comparisons with appropriate guides, limits and standards and with background levels from natural or other non-Plant sources provide a basis for concluding that no adverse environmental effects were attributable to the operation of Rocky Flats Plant.

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I. INTRODUCTION

The Rocky Flats Plant is a government-owned and contractor-operated facility. It is part of a nationwide nuclear weapons research, development, and production complex administered by the Albuquerque Operations Office of the U.S. Department of Energy (DOE). The prime operating contractor for the Rocky Flats Plant is the Energy Systems Group of Rockwell International.

The Rocky Flats Plant is located at 105°11'30" west longitude and 39°53'30" north latitude in northern Jefferson County, Colorado. The Plant is approximately 26 kilometers (16 miles) northwest of downtown Denver and is almost equidistant from the cities of Boulder, Golden, and Arvada (see Figure 1). The site consists of 2,650 hectares (6,500 acres) of federally owned land. As shown in Figure 2, major Plant structures are located within a security-fenced area of 155 hectares (385 acres).

The Plant is a key DOE facility that produces components for nuclear weapons; therefore, its product is directly related to national defense. The Plant is involved in fabricating components from plutonium, uranium, beryllium, and stainless steel. Production activities include metal fabrication and assembly, chemical recovery and purification of process-produced transuranic radionuclides, and related quality control functions. Research and engineering programs supporting these activities involve chemistry, physics, materials technology, ecology, nuclear safety, and mechanical engineering.

As part of DOE's energy research programs, a Wind Systems Test Center has been constructed in the northwest corner of the Rocky Flats Plant site to test small wind-energy machines. This test facility is a national research center for the development and testing of wind energy devices.

The more than 100 structures on the Plant site contain about 189,000 square meters (2.03 million square feet) of floor space. Of this space, major manufacturing, chemical processing, plutonium recovery, and waste treatment facilities occupy about 156,000 square meters (1.68 million square feet). Major laboratory and research b uildings occupy about 13,850 square meters (149,000 square feet). The remaining floor space is divided among administrative, utility, security, warehousing, storage, and construction contractor facilities.

All of the Plant's heating requirements are met by in-plant steam boilers that normally use natural gas but are also capable of using fuel oil. During Calendar Year 1981, approximately 23.9 million cubic meters (845 million cubic feet) of natural gas were used. No fuel oil was used during 1981. Raw water is purchased from the Denver Water Board and is drawn from Ralston Reservoir and the South Boulder Diversion Canal. The Rocky Flats Plant used approximately 428 million liters (113 million gallons) of water during 1981.

The piedmont of the Front Range of the Rocky Mountains rises 8 kilometers (5 miles) west of the site and crests at the Continental Divide, which is 32 kilometers (20 miles) from the Plant. The natural environment of the Plant site and vicinity is influenced primarily by the Front Range of the Rocky Mountains and the site elevation, which is 1,829 meters (6,000 feet) above sea level. The surficial geology of Rocky Flats consists of a thin layer of gravelly topsoil underlain by a 6- to 15-meter (20- to 49-foot) thick layer of coarser, clayey gravel. This is underlain by an impermeable bedrock structure upon which Plant building foundations are supported. Area hydrology is influenced by the topsoil, which consists of gravelly and highly permeable alluvium. Water retention in the soil is poor, and vegetation in the

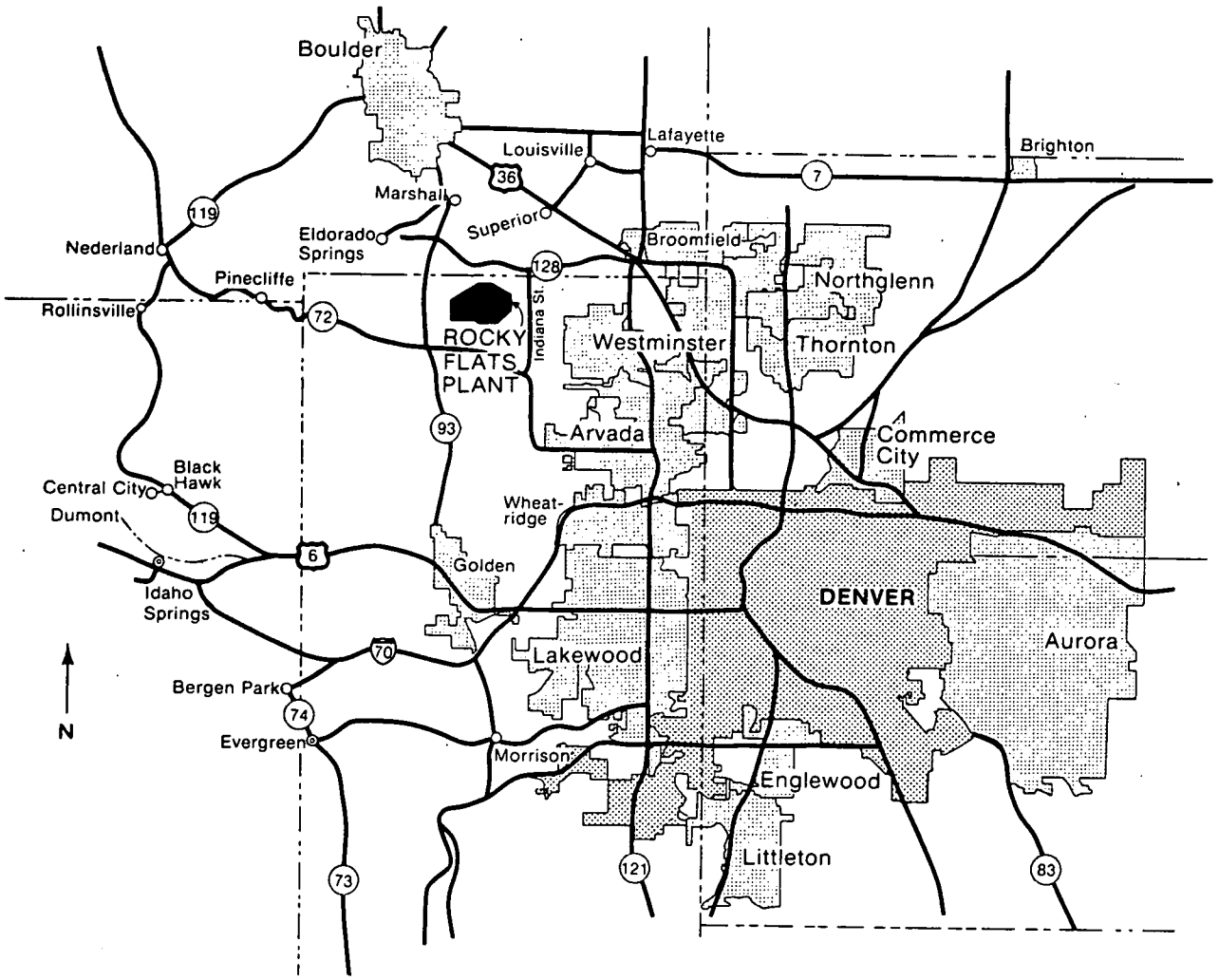

FIGURE 1. Area Map of Rocky Flats Plant and Surrounding Communities

area is sparse. Cactus, spanish bayonet, and grasses representative of a mixed short- and mid-grass plain constitute the main ground cover, and cottonwood trees grow adjacent to watercourses. Introduced Eurasian weeds also make up part of the flora. The geographic features of the Plant, in combination with rocky soil, low rainfall, high winds, and solar radiation, produce harsh, semiarid conditions.

The climate at Rocky Flats is characterized by dry, cool winters and warm, somewhat moist summers. There is considerable clear-sky sunshine, and the average precipitation and relative humidity are low. The elevation of the Plant and the major topographical features of the area significantly influence the climate and meteorological dispersion characteristics of the site.

Winds at Rocky Flats, although variable, are predominantly westerly, with stronger winds occurring during the winter. During 1981, approximately 53 percent of the winds had a westerly component.

Annual average precipitation at the Rocky Flats Plant is slightly over 38.1 centimeters (15 inches). The maximum annual precipitation recorded over a 24-year period was 63.17 centimeters (24.87 inches) in 1969. Typically, more than 80 percent of the precipitation falls as rain between April and

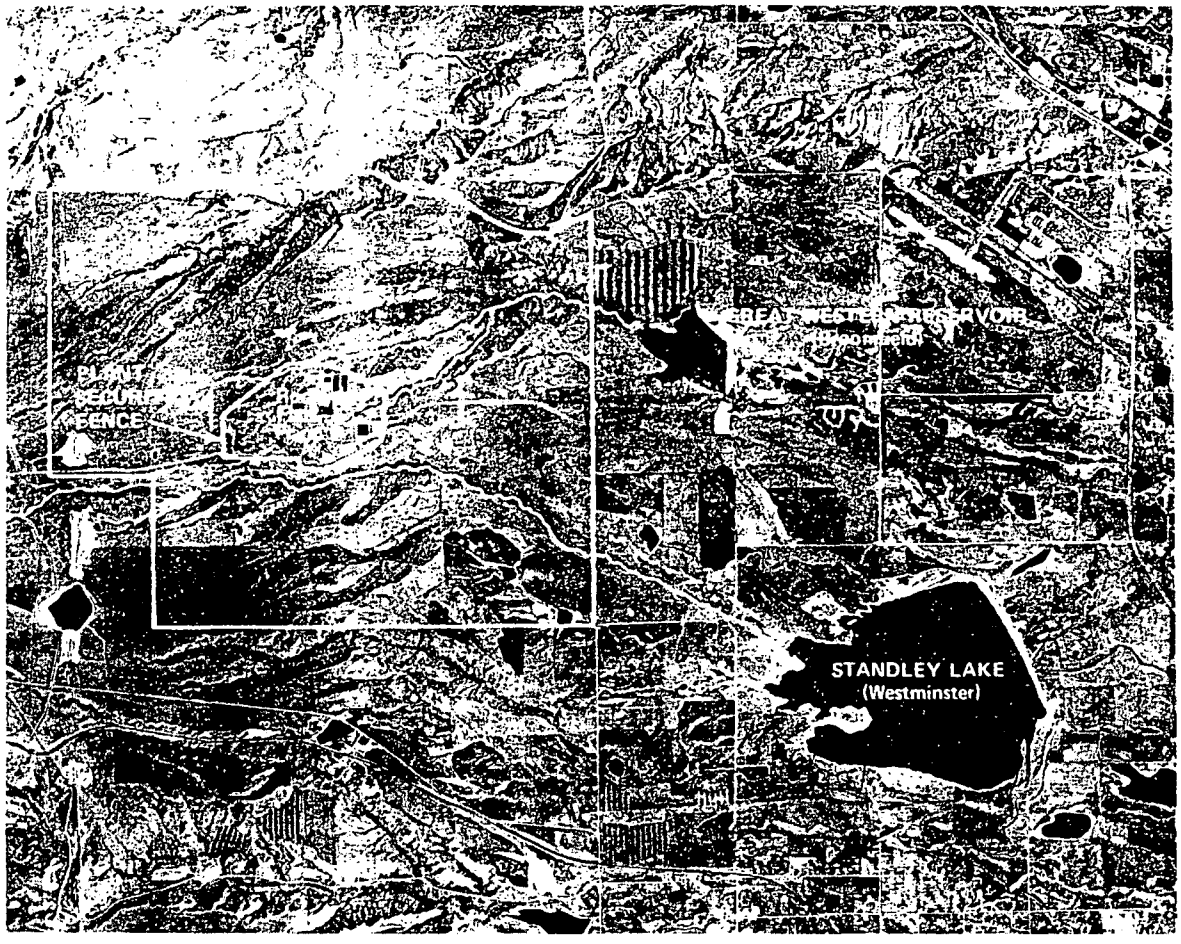

FIGURE 2. Aerial Photograph of the Rocky Flats Plant and Immediate Vicinity

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September. Most of the remaining precipitation is in the form of snow.

Air in production and research facilities is continuously discharged to the atmosphere by 43 ventilation exhaust systems. Prior to atmospheric discharge, the exhaust air passes through particulate filtration systems. These filtration systems employ High Efficiency Particulate Air (HEPA) filters, which are purchased to equal or exceed the DOE specified filtration efficiency of 99.97 percent for 0.3-μm particles. Prior to installation in the filter plenums, each filter is tested at the Plant to ensure that the filtration efficiency is not less than the 99.97 percent standard. Airborne radioactivity released to the environment from process operations is kept to a minimum and is well within Plant health and safety guidelines.

As shown in Figure 3, surface water runoff from the Plant is from west to east. Runoff is carried from the Plant by three major drainage basins that are tributary to Walnut Creek on the north and to Woman Creek on the south. The south fork of Walnut Creek receives most of the stormwater runoff from areas surrounding Plant buildings. Also shown in Figure 3 and in Figure 2 is the confluence of the north and south forks of Walnut Creek, which is 1.1 kilometers (0.7 mile) west of the eastern perimeter of the Plant. Great Western Reservoir, a water supply for a part of the City of Broomfield, is 1.6 kilometers (1 mile) east of this confluence. Woman Creek flows east from Rocky Flats into Standley Lake, a water supply for the city of Westminster and for portions of the cities of Northglenn and Thornton. Ponds on the north fork of Walnut

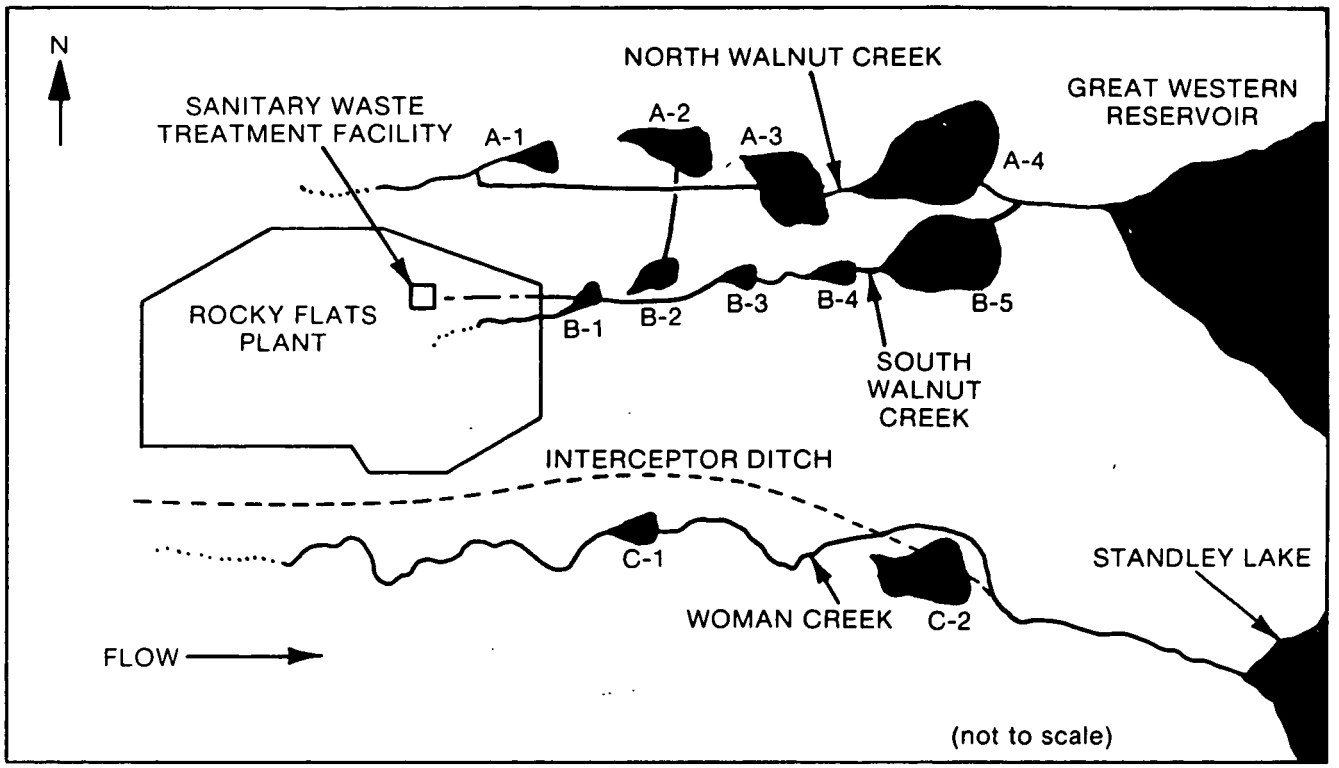

FIGURE 3. Holding Ponds and Liquid Effluent Watercourses

Creek are designated A-1 through A-4 (see Figure 3). Ponds on the south fork are designated B-1 through B-5. These ponds receive runoff and/or treated sanitary wastewater. Pond C-1 is located on the Woman Creek watercourse. Pond C-2, located near the Woman Creek watercourse, receives surface runoff water from an interceptor ditch parallel to the south side of Plant production areas.

Certain operations at the Rocky Flats Plant involve or produce radioactively contaminated liquids, solids, and gases. Radioactive materials are handled in accordance with stringent procedures and within multiple containments (physical barriers) designed to minimize the release of contaminants to the environment. The radioactive waste systems include collection, filtration, liquid processing, and temporary storage facilities for those process wastes known, or suspected, to have been in contact with radioactive materials. The liquid waste process system concentrates liquid wastes containing unrecoverable radioactive materials into solid wastes suitable for shipment, along with other contaminated solid wastes, to a DOE-approved storage facility. Specific details of Plant waste processing facilities are described in the Rocky Flats Plant Site Final Environmental Impact Statement.[1]

Sanitary waste is processed by the sanitary waste treatment plant and is isolated from process waste throughout the Plant. Conditioning chemicals are added to destroy biologically degradable organic wastes. The treatment plant is of the activated sludge type and has three stages of treatment. It has a design capacity of 1,700,000 liters (450,000 gallons) per day. Present daily flows usually vary between 570,000 and 950,000 liters (150,000 and 250,000 gallons) per day. One of two 265,000-liter (70,000-gallon) preaeration holding tanks, located upstream from the sewage plant, serves as a surge basin to smooth out peak flows. A second holding tank provides storage capacity for sanitary wastes from plutonium process areas, should emergency retention be required. Liquid effluents from

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the sanitary waste treatment plant either are released to holding ponds for subsequent onsite irrigation or are pumped to a reverse osmosis facility for further treatment. After treatment, product water from the reverse osmosis facility can be used in Plant cooling towers or for spray irrigation.

Residual solids from the sanitary waste treatment plant are concentrated, dried, packaged, and shipped to a DOE-approved storage facility. Reverse osmosis brine is sent to process waste treatment for evaporation and drying, and the salts are packaged and shipped to a DOE-approved storage facility.

Nonradioactive solid wastes are transferred to an onsite sanitary landfill for disposal. This landfill was designed and constructed in 1974 as a disposal site for nonradioactive waste materials. It includes an impervious clay seal layer and diversion ditches. Routine materials are checked daily for radioactivity at the landfill site before final burial. The disposal of nonroutine or special waste materials is administratively controlled.

Groundwater and surface water flow in and around the sanitary landfill is controlled by interceptor trenches and by french drains. The trenches divert all upgradient waters around the landfill. The drains collect groundwater from the perimeter of the landfill and divert it around a holding pond. The holding pond collects subsurface drainage from the landfill. Water samples from this holding pond, drains, and three test wells in the vicinity are collected periodically and are analyzed for pollutants and radioactivity.

Land use at Rocky Flats Plant is managed by Rockwell International and the Department of Energy. This includes land utilization planning and environmental and physical control of the land. All major activities conducted on Plant site land require approval by the Rockwell Executive Committee based upon recommendations of a Land Management Council. The Council evaluates all research projects and other nonroutine activities on Plant lands by means of a Land Use Request system. The effects of such activities on Plant land are evaluated by Environmental Sciences personnel through field observations and remote sensing techniques.

Personnel in the Environmental Sciences Branch of Rockwell International conduct an extensive environmental surveillance program at the Plant. This program is designed to provide assurance that the many safeguards at the Plant effectively limit the release of radioactive or toxic materials. Environmental Sciences personnel assist various operating groups in adhering to the DOE policy that ". . .operations shall be conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable."[2]

The environs are monitored for ionizing radiation and for pertinent radioactive, chemical, and biological pollutants. Air, water, soil, and vegetation are sampled on the Plant site and throughout the surrounding region. Several Federal, State, and local governmental agencies independently conduct additional environmental surveys on and off the Plant site. The Colorado Department of Health samples air, soil, and water at the Rocky Flats site and in surrounding communities. It also operates an onsite, continuous, particulate air sampler for the Jefferson County Health Department. The DOE Environmental Measurements Laboratory (EML) conducts particulate air sampling at the Rocky Flats Plant and periodically performs special studies, including sediment and soil sampling and analysis. Additional special sampling has been performed by the U.S. Environmental Protection Agency (EPA).

Plutonium concentrations in this report represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the Plant. Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Fully enriched and depleted uranium are the principal types of uranium handled at Rocky Flats. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium; however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from

uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The Radioactivity Concentration Guides[2] (RCG's) used in this report for uranium in air and water are those for uranium-233, -234, and uranium-238, respectively, which are the most restrictive guides.

The information contained in this report is submitted in compliance with Department of Energy Order 5484.1, Chapter IV, and is a compilation of data provided monthly to the DOE Rocky Flats Area Office, the Radiation and Hazardous Waste Control Division of the Colorado Department of Health, Region VIII of the EPA, the health departments of Boulder and Jefferson Counties, and to interested city officials in communities near the Plant.

II. SITE METEOROLOGY AND CLIMATOLOGY

Wind, temperature, and precipitation data were collected at different locations on the Plant site during 1981. Wind and temperature data were summarized from analog charts onto which the raw data had been recorded. Precipitation amounts were measured daily and recorded in a tabular format.

Table 1 is an annual summary of the percent frequency of wind directions (16 compass points) divided into four speed categories. The compass point designations indicate the true bearing when facing against the wind. These frequency values are presented graphically in the form of a wind rose in Figure 4. The wind rose vectors also represent the bearing against the wind (i.e., wind along each vector blows toward the center). The predominance of northwesterly (from northwest to southeast) winds is typical of Rocky Flats. The low frequency of winds greater than 7 meters per second [m/s (15.6 mph)] with easterly components is also normal.

Temperature data are summarized in Table 2, which shows the 12 monthly maximum and 12 monthly minimum temperatures, along with the average monthly maximums and minimums for the 24 years for which data are available (1953-1976). Averages of the daily maximum and minimum temperatures are shown, along with the appropriate 24-yr averages for each month.

TABLE 1. Wind Direction Frequency (Percent), by Four Wind-Speed Classes, at the Rocky Flats Plant During 1981[a]

	Calm	1-3 (m/s)[b]	3-7 (m/s)	7-15 (m/s)	> 15 (m/s)	Total
–	3.79	–	–	–	–	3.79
N	–	2.42	5.87	0.65	0.00	8.94
NNE	–	1.73	3.84	0.48	0.00	6.05
NE	–	1.55	2.07	0.13	0.00	3.75
ENE	–	1.69	1.51	0.08	0.00	3.28
E	–	1.58	1.28	0.00	0.00	2.86
ESE	–	1.72	1.37	0.04	0.00	3.12
SE	–	1.64	1.72	0.01	0.00	3.37
SSE	–	3.29	3.01	0.08	0.00	6.39
S	–	2.29	3.31	0.06	0.00	5.66
SSW	–	1.92	2.80	0.22	0.00	4.94
SW	–	1.66	2.19	0.21	0.00	4.06
WSW	–	2.26	2.74	0.19	0.01	5.20
W	–	2.15	4.00	0.79	0.06	7.00
WNW	–	2.22	4.72	3.25	0.28	10.47
NW	–	2.67	5.61	2.55	0.29	11.13
NNW	–	2.93	5.82	1.11	0.12	9.98
Totals	3.79	33.74	51.86	9.85	0.76	100.00

a. Data obtained from sensors located ~ 10 m (33 ft) above the ground.
b. For conversion purposes, miles per hour (mph) equals 2.237 multipled by meters per second (m/s).

A summary of monthly water-equivalent precipitation is shown in Figure 5, along with the 1953-1976 monthly average for comparison. The drought of 1980-1981 is particularly evident in the January and February data. Most other months also recorded below-average precipitation. Exceptions were May and August when precipitation was much above average and December when near-normal precipitation was recorded. The annual precipitation of 33.12 cm was 14 percent below the 24-yr mean of 38.50 cm.

III. MONITORING SUMMARY

During 1981, the Rocky Flats Plant conducted an environmental monitoring program that included the sampling and analysis of airborne effluents, ambient air, surface water, groundwater, soil, and vegetation. Measurements of external

FIGURE 4. 1981 Annual Wind Rose for the Rocky Flats Plant

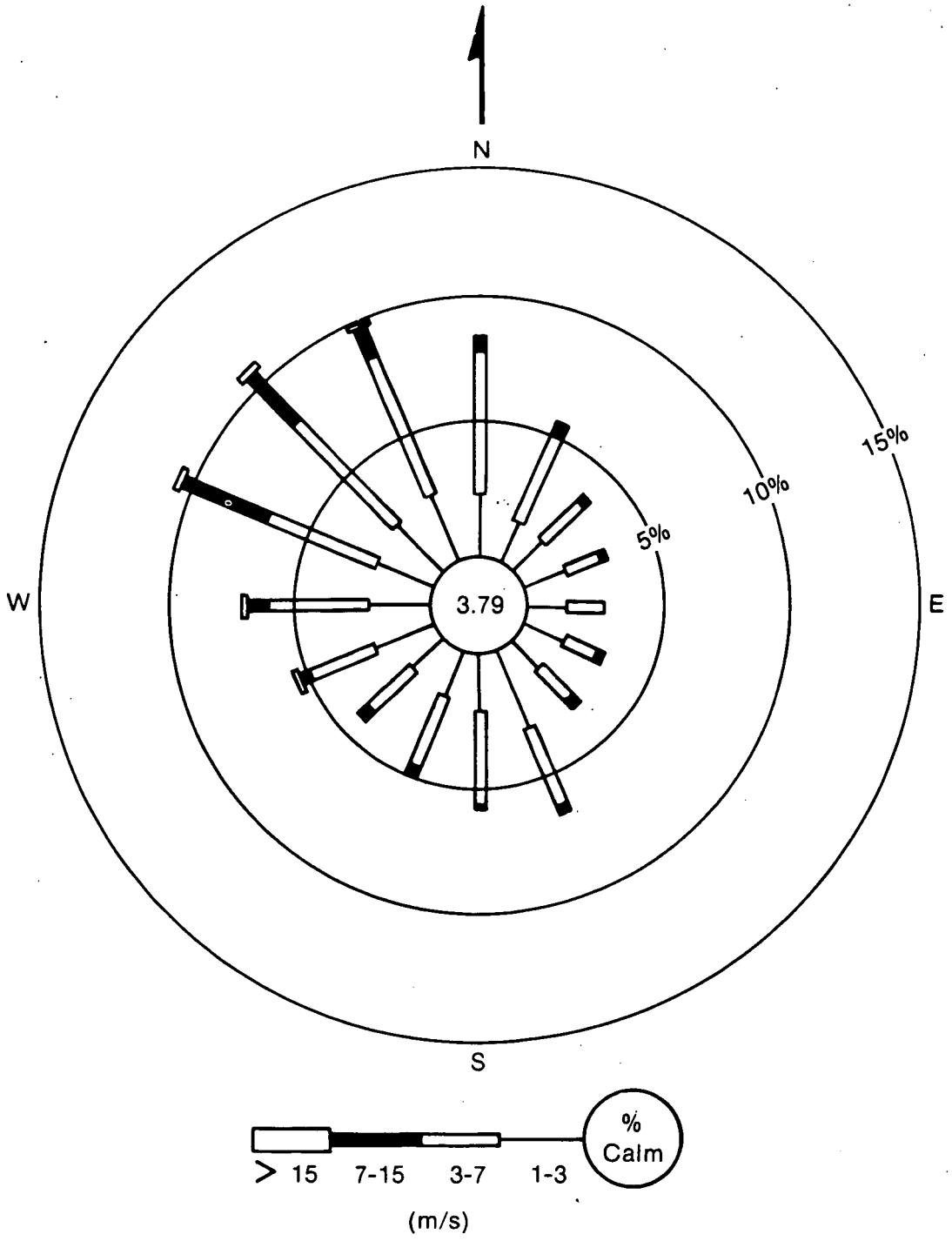

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TABLE 2. Monthly Temperature Data*

Month	Monthly Maximum		Monthly Minimum		Average of the Daily Maximums		Average of the Daily Minimums	
	1981	24-yr Average	1981	24-yr Average	1981	24-yr Average	1981	24-yr Average
January	15.5	15.2	-10.0	-20.5	7.3	4.1	-2.4	-6.5
February	19.0	16.4	-24.0	-15.6	8.2	6.5	-4.0	-4.7
March	19.0	20.1	-5.5	-14.8	8.9	8.4	-1.4	-3.3
April	28.0	23.9	-2.0	-7.9	18.8	13.1	6.1	1.4
May	26.5	27.9	0.0	-0.8	16.0	18.8	6.4	7.2
June	33.0	32.7	6.5	5.1	26.4	24.5	13.0	12.1
July	34.5	34.2	9.5	10.7	25.7	28.2	15.4	15.8
August	31.5	33.7	11.0	9.2	25.0	27.5	14.4	15.0
September	28.0	30.6	9.0	2.1	24.5	22.4	13.8	10.2
October	24.5	26.8	-3.0	-4.3	16.3	17.4	5.8	5.3
November	23.0	20.1	-5.5	-12.9	13.3	9.9	3.6	-1.2
December	18.0	17.4	-10.0	-17.0	7.9	6.7	-0.7	-4.2

*All temperatures are reported in degrees centigrade.

penetrating gamma radiation exposure were also taken using thermoluminescent dosimeters. The program consisted of collecting samples at onsite, boundary, and offsite locations. An aerial radiological survey of the Plant was conducted by EG&G, Inc. consisting of measurement of gamma radiation from terrain surface in and around the Plant. Ambient air quality monitoring and monitoring of water for trace quantities of toxic materials, metals, nitrates, biocides, herbicides, and polychlorinated biphenyls also were performed. Specific details of the routine Rocky Flats Environmental Monitoring Program are documented in an Environmental Monitoring Catalogue that was published in 1980 and remained in effect throughout 1981.[3]

Particulate and tritium sampling of building exhaust systems was conducted continuously. Emission data derived from analysis of those samples were in the ranges normally expected and presented no significant insult to the environment.

Particulate samples also were collected from ambient air samplers operated continuously onsite, at the Plant perimeter, and at nine community locations. Analysis of the samples indicated that the concentrations of airborne plutonium at all locations were far below applicable Radioactivity Concentration Guides (RCG's).[2,4] At the Plant perimeter locations, the 1981 average plutonium concentration in ambient air was 6.66×10^{-7} Bq/m^3 (0.018×10^{-15} μCi/mℓ).* The average plutonium concentration at the community locations was 7.03×10^{-7} Bq/m^3 (0.019×10^{-15} μCi/mℓ). These values are 0.10 percent or less of the applicable DOE and Colorado Department of Health RCG's[2,4] and less than 2 percent of the proposed EPA guidance for transuranium elements in ambient air.[5]

During the last quarter of 1981, monitoring of ambient air for total suspended particulates (TSP) and ozone (O_3) was performed. This program was conducted through utilization of a self-contained, Mobile Ambient Air Monitoring (MAAM) van. Ozone and TSP are regulated by the EPA's National Ambient Air Quality Standards (NAAQS) in the 1970 Clean Air Act.[6] The TSP data for 17 monitoring periods had a geometric mean of 33 μg/m^3. Direct comparison of the limited TSP and ozone data collected to the NAAQS could not be made since compliance concentrations are based on annual sets of data; however, the TSP and ozone data generally indicated that the NAAQS air quality compliance levels are being met.

*1 Bq (becquerel) = 1s^{-1} ($\approx 2.7 \times 10^{-11}$ Ci).

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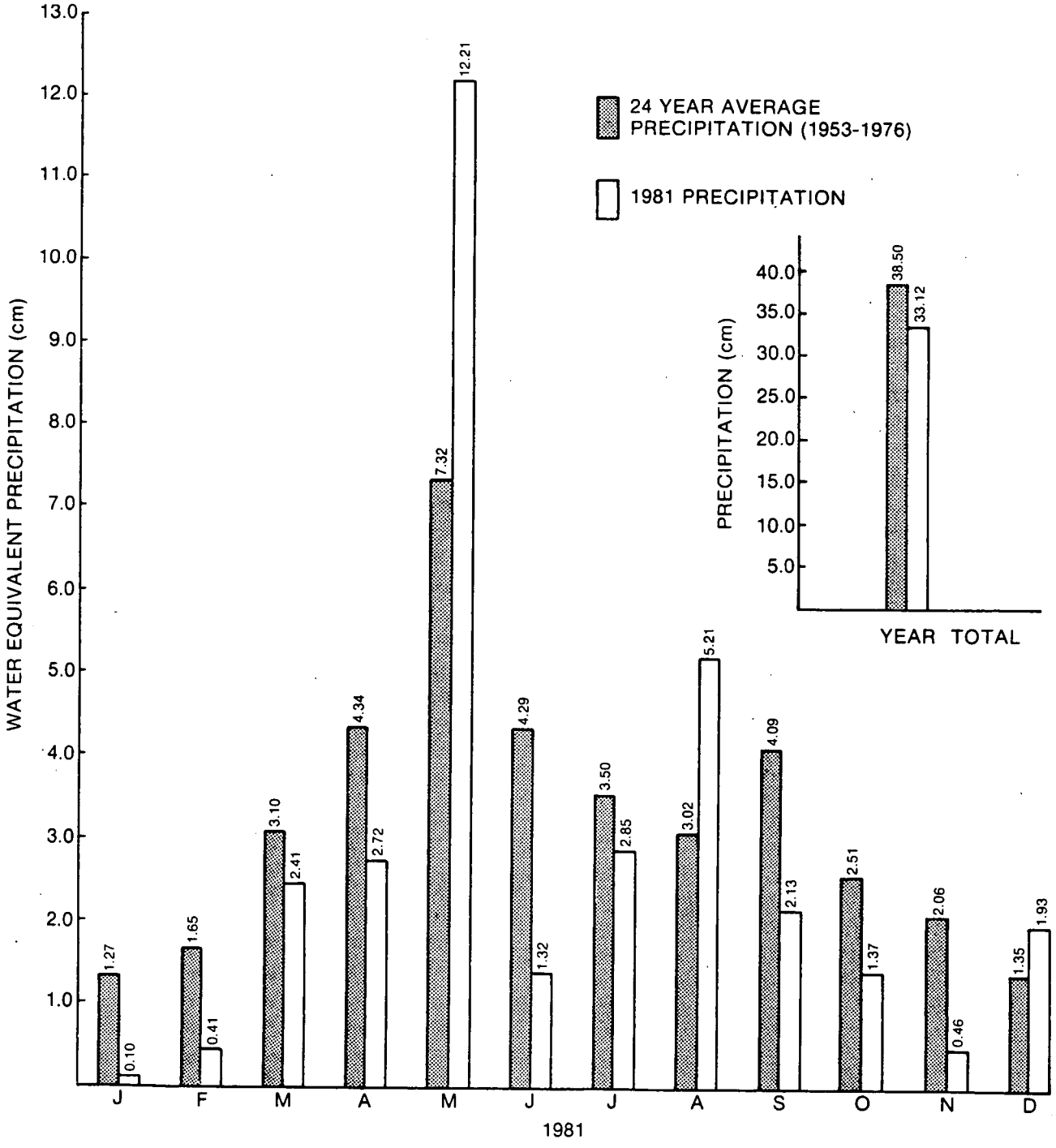
FIGURE 5. Monthly and Annual Water-Equivalent Precipitation at the Rocky Flats Plant



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All water used during 1981 for Plant process operations and sanitary purposes was treated and evaporated and/or reused for cooling tower makeup, steam plant use, or for spray irrigation within the Plant boundaries. This program has continued since 1980.

Surface runoff from precipitation was collected by three surface water control ponds, A-4, B-5, and C-2. After being monitored, the water was discharged offsite. Those discharges were monitored for compliance with a new EPA National Pollutant Discharge Elimination System (NPDES) permit.[7] There were no NPDES permit violations during 1981.

Routine water monitoring was conducted for several public water supplies and for tap water in nine communities. The average radioactivity concentrations for plutonium, uranium, americium, and tritium measured at those locations were found to be 17 percent or less of the applicable RCG's.[2, 4] In addition, the sum of the average concentrations for plutonium and americium in all community drinking water samples was 0.07 percent or less of the State of Colorado regulations for alpha-emitting radionuclides[4] and the EPA National Interim Primary Drinking Water Regulations.[8] Average concentrations of tritium in community drinking water samples were all within local background range and were 2.0 percent or less of the applicable State of Colorado and EPA drinking water standards.[4, 8]

Groundwater monitoring was conducted three times during 1981 at 49 sampling locations. Tritium and uranium have been detected at low concentrations in monitoring wells close to solar evaporation ponds that have been used to store process wastewater. The concentrations of plutonium, uranium, americium, and tritium at all locations were well below the DOE and Colorado Department of Health RCG's for surface water discharged to uncontrolled areas.[2, 4]

Biocides and herbicides are used for pest and weed control at the Rocky Flats Plant. Water samples collected during the period of application indicated concentrations of the chemicals well below recommended concentration limits. Also, polychlorinated biphenyl (PCB) monitoring showed no detectable concentrations above a detection limit of approximately one part per billion.

The 1981 soil sampling program was conducted as part of a long range program designed to study possible migration of plutonium in soil and to provide data for comparison with the EPA proposed guidance on transuranium elements in the environment.[5] At two onsite sampling locations, a total of 18 samples was collected, analyzed, and the resulting data were compared to EPA guidance values. The median concentrations of plutonium for the two locations were 12.6×10^8 Bq/km^2 (34 mCi/km^2) and 40.0×10^8 Bq/km^2 (108 mCi/km^2). These values are 17 percent and 54 percent, respectively, of the EPA proposed guideline for transuranium elements in soil. Surface and core samples were collected at one onsite location to support a plutonium migration study. The plutonium concentrations of the surface samples ranged from 263 to 844 Bq/kg (7.10 to 22.8 pCi/g). The plutonium concentration for the core samples ranged from 9.03 to 69.6 Bq/kg (0.244 to 1.88 pCi/g). These values, which will be compared to future values, are not significantly different from those reported in 1980.

The 1981 environmental measurement of external penetrating gamma radiation, using thermoluminescent dosimeters (TLD's), showed that the annual dose equivalent at onsite, Plant perimeter, and community locations was within the range of regional background.

Potential public radiation dose commitments, which could have resulted from Plant operations, were calculated from average radionuclide concentrations measured at the DOE property boundaries and in surrounding communities. Dose assessment for 1981 was conducted for the DOE property (site) boundary, nearby communities, and to a distance of 80 km (50 mi). At the Plant boundary, the maximum 70-yr dose commitment to an individual was calculated to be 6×10^{-7} Sv* (6×10^{-5} rem) to the total body, and 9×10^{-6} Sv (9×10^{-4} rem) to the bone. By comparison, annual doses to the body and bone from natural radiation in the Denver area are 1.50×10^{-3} and 1.68×10^{-3} Sv

*1 Sv (sievert) = 1 J kg^{-1} = 100 rem

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(0.15 and 0.17 rem) per year, respectively.[9] The 70-yr dose commitments of 6×10^{-7} Sv and 9×10^{-6} Sv (6×10^{-5} and 9×10^{-4} rem) represent less than 0.02 percent and less than 0.06 percent, respectively, of the DOE radiation protection standards.[2]

For community locations, the maximum radiation dose resulted in a 70-yr dose commitment of 3×10^{-8} Sv (3×10^{-6} rem) to the total body and 8×10^{-6} Sv (8×10^{-4} rem) to the bone. This represents less than 0.002 percent and less than 0.2 percent, respectively, of the annual DOE standards[2] based on average dose for a suitable sample of the exposed population. These values include contribution from fallout caused by atmospheric weapons testing. The 70-yr total body dose commitment to the population living within 80 km (50 mi) of the Plant was based on the maximum community dose estimates. For the maximum community, the specific organ doses were all less than the value specified by DOE as de minimis, or inconsequential. The dose commitment for all individuals to a distance of 80 km was, therefore, considered to be de minimis.

IV. MONITORING DATA: COLLECTION, ANALYSES, AND EVALUATION

This section describes the environmental monitoring program for 1981, results of sample analyses, and evaluation of the data with regard to applicable guides and standards. The reader is directed to the appendixes at the end of this report for detailed information concerning applicable guides and standards, quality control, analytical procedures, detection limits, error term propagation, and reporting of minimum detectable concentrations and error terms. Appendix D includes a discussion of the methodology used for reporting measurements that were at or below the minimum detectable concentrations (MDC). This appendix also discusses the use of negative values. Appendix E explains the use of the less-than sign (<) and defines the use of plus or minus (±) error terms in the data reported.

A. Airborne Effluent Monitoring

Production and research facilities at Rocky Flats are equipped with 43 ventilation exhaust systems. Particulates, generated by production and research activities, are entrained by exhaust air streams. These particulate materials are removed from the air stream in each exhaust system by means of High Efficiency Particulate Air (HEPA) filters. Residual particulates in each of these systems are continuously sampled downstream from the final stage of the HEPA filters. For immediate detection of abnormal conditions, ventilation systems that service areas containing plutonium are equipped with selective alpha air monitors. These monitors are sensitive to specific radionuclides, including plutonium-239 and -240, and are tested and calibrated routinely to maintain sensitivity. The monitors alarm automatically if out-of-tolerance conditions are experienced. No such conditions occurred during 1981.

Three times each week, particulate samples are collected from each exhaust system and radiometrically analyzed for long-lived alpha emitters. Concentrations of long-lived alpha emitters are indicative of the overall performance of the filtration systems. If the total long-lived alpha concentration for an effluent sample exceeds the Plant action guide value of 7.4×10^{-4} Bq/m^3 (0.020×10^{-12} μCi/mℓ), a followup investigation is conducted to determine the cause and to establish corrective action.

At the end of each month, samples from each ventilation system are composited into a single sample for specific chemical analysis. An aliquot of each of the dissolved, composite samples from the 43 Plant exhaust systems is analyzed for beryllium particulates using a flameless atomic absorption spectrometry technique.[10] The remainder of the dissolved sample undergoes chemical separation and subsequent alpha spectral analysis to quantify specific alpha-emitting radionuclides. Analyses for uranium isotopes are conducted on the composite samples from each of the 43 exhaust systems. Thirty-four of the ventilation exhaust systems are located in buildings that contain plutonium. Particulate samples from those 34 systems are also analyzed for specific isotopes of plutonium.

Continuous sampling for tritium is conducted in 23 ventilation exhaust systems. A bubbler-type sampler is used to collect samples three times each week. Tritium concentrations in the sample

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are measured on a liquid scintillation photospectrometer.

Table 3 presents the quantitative data for radioisotopes in airborne effluents during 1981. Tritium values include contributions from background radioactivity.

During 1981 the total quantity of plutonium discharged to the atmosphere from 34 ventilation exhaust systems was less than 3.045×10^5 Bq (8.23 μCi). The total discharge of uranium from 43 exhaust systems was less than 1.105×10^6 Bq (29.86 μCi). The tritium discharged from 23 ventilation systems was 1.65×10^{10} Bq (0.447 Ci). The maximum tritium concentration of 1.14×10^4 Bq/m^3 ($309{,}000 \times 10^{-12}$ μCi/mℓ) was measured during a 2-day period in January in an exhaust system that discharges small volumes of air, compared to most other systems on the Plant. The quantity of tritium from this discharge [$\sim 3.7 \times 10^9$ Bq (0.10 Ci)] presented no adverse environmental impact.

Table 4 presents the beryllium airborne effluent data for 1981. The total quantity of beryllium released from the 43 ventilation exhaust systems was 0.202 g.

B. Radioactive Ambient Air Monitoring

High-volume ambient air samplers are located on the Rocky Flats Plant site, at the Plant perimeter [at a distance of approximately 3 to 6 km (2 to 4 mi) from the Plant center], and in surrounding communities. These Rocky Flats-designed air samplers operate continuously at a volume flow rate of approximately 19 ℓ/sec (40 ft^3/min), collecting particulates on 20- X 25-cm (8- X 10-in.) Delbag Microsorban® filter media. The effectiveness of the high-volume sampler and the filter media has been evaluated by Dr. James B. Wedding from Colorado State University.[12] According to Wedding, the Rocky Flats design compared favorably to the EPA-specified standard Hi-Volume Sampler for a variety of simulated field conditions. The filter media was found to be greater than 99.9 percent efficient for particle sizes and pressure drops typical of conditions encountered in routine ambient air sampling.

Airborne particulates in ambient air are sampled continuously at 23 locations within and adjacent to the Rocky Flats exclusion area (Figure 6). The sample filters are collected weekly and analyzed for total long-lived alpha (TLLα). If TLLα concentration for an ambient air sample exceeds a Plant guide value [3.7×10^{-4} Bq/m^3 (10×10^{-15} μCi/mℓ)] specific plutonium analysis is performed. During 1981, all TLLα concentrations were less than the guide value.

On a routine basis, filters from 9 of the 23 samplers were composited and analyzed biweekly for plutonium. Table 5 contains the average concentrations of plutonium in ambient air at these nine onsite stations during 1981. The calculated value for the average concentration at each location is referred to as the "point estimate." For each plutonium concentration point estimate, a Lower Confidence Limit (LCL) and an Upper Confidence Limit (UCL), which define a 95 percent confidence interval, have been included in the table. The derivation of the point estimates, the LCL, and the UCL is discussed in Appendix E. The average concentrations of plutonium in ambient air at the nine onsite stations during 1981 ranged from 9.99×10^{-7} to 2.03×10^{-5} Bq/m^3 (0.027×10^{-15} to 0.549×10^{-15} μCi/mℓ). These concentrations were less than 1.03 percent of the RCG_a for soluble plutonium in ambient air in uncontrolled areas.[2, 4]

Monitoring for tritium in ambient air water vapor is conducted at onsite locations S-4, S-5, and S-16 (Figure 6). Samples are collected and analyzed weekly. The tritium sampler utilizes a 1 ℓ/min air pump that operates continuously. The sample is collected in a Pyrex tube filled with silica gel, which collects moisture from the ambient air. The equipment is contained in an aluminum case that is insulated, weathertight, and lockable. Temperature inside the case is controlled by a small heater and fan that maintains a temperature between 4.44 and 32.2 °C (40 and 90 °F). Table 6 presents the average concentrations of tritium in ambient air water vapor at these three onsite stations during 1981. The maximum average concentration of tritium in ambient air at the three

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TABLE 3. Radioisotopes in Airborne Effluents

Sample Period	Plutonium[a] Number of Analyses	Plutonium Total Discharge (μCi)	Plutonium C_{max}[c] ($\times 10^{-12}$ μCi/mℓ)	Uranium[b] Number of Analyses	Uranium Total Discharge (μCi)	Uranium C_{max} ($\times 10^{-12}$ μCi/mℓ)	Tritium Number of Analyses	Tritium Total Discharge (Ci)	Tritium C_{max} ($\times 10^{-12}$ μCi/mℓ)
January	30	0.35	0.0024 ± 0.0002	40	1.79	0.109 ± 0.009	182	0.169	309000 ± 1000
February	30	0.18	0.0033 ± 0.0003	38	1.61	0.0065 ± 0.0005	180	0.054	2800 ± 200
March	35	0.30	0.0014 ± 0.0001	42	4.05	0.148 ± 0.008	195	0.024	560 ± 70
April	32	0.68[d]	0.0026 ± 0.0004	39	2.47	0.13 ± 0.01	195	0.020	1700 ± 200
May	31	0.25	0.0035 ± 0.0001	42	2.57	0.032 ± 0.005	195	0.020	1700 ± 200
June	36	1.54	0.0134 ± 0.0004	45	2.02	0.040 ± 0.004	260	0.028	1100 ± 100
July	34	1.17	0.0128 ± 0.0004	42	2.87	0.016 ± 0.002	280	0.023	250 ± 50
August	34	0.18	0.0010 ± 0.0002	42	2.13	0.0155 ± 0.0009	260	0.020	430 ± 60
September	34	0.67	0.0078 ± 0.0005	42	1.34	0.0084 ± 0.0004	260	0.019	310 ± 50
October	40	0.98	0.0047 ± 0.0002	48	5.12	0.29 ± 0.02	260	0.029	290 ± 40
November	35	1.37	0.033 ± 0.002	43	1.34	0.0060 ± 0.0003	260	0.021	610 ± 70
December	35	0.56	0.0036 ± 0.0004	43	2.55	0.029 ± 0.002	260	0.020	180 ± 90
Summary	406	8.23	0.033 ± 0.002	506	29.86	0.29 ± 0.02	2787	0.447	309000 ± 1000

a. Radiochemically determined as plutonium-239, -240.
b. Radiochemically determined as uranium-233, -234, and -238.
c. C_{max} is the maximum measured concentration.
d. This value includes an estimated discharge for one exhaust system for which one sample analysis did not meet quality acceptance criteria. The estimate is based on the average concentration in the system for the previous six months.

TABLE 4. Beryllium in Airborne Effluents

Sample Period	Number of Analyses	Total Discharge* (g)	C_{max} (μg/m³)
January	40	-0.049	0.0008
February	38	0.027	0.0006
March	42	-0.047	0.0003
April	39	0.057	0.0008
May	42	0.018	0.0014
June	45	0.095	0.0026
July	42	-0.024	0.0001
August	42	0.067	0.0002
September	42	0.002	0.0003
October	48	-0.022	0.0025
November	43	0.006	0.0004
December	43	0.072	0.0004
Summary	506	0.202	0.0026

*The beryllium stationary source emission standard is no more than 10 g of beryllium over a 24-hr period under the provision in subpart C of 40 CFR 61.32(a).[11]

onsite stations during 1981 was less than 1.5×10^{1} Bq/ℓ ($< 400 \times 10^{-9}$ μCi/mℓ). This concentration was less than 0.04 percent of the RCG_W for tritium in water released to uncontrolled areas.[2,4]

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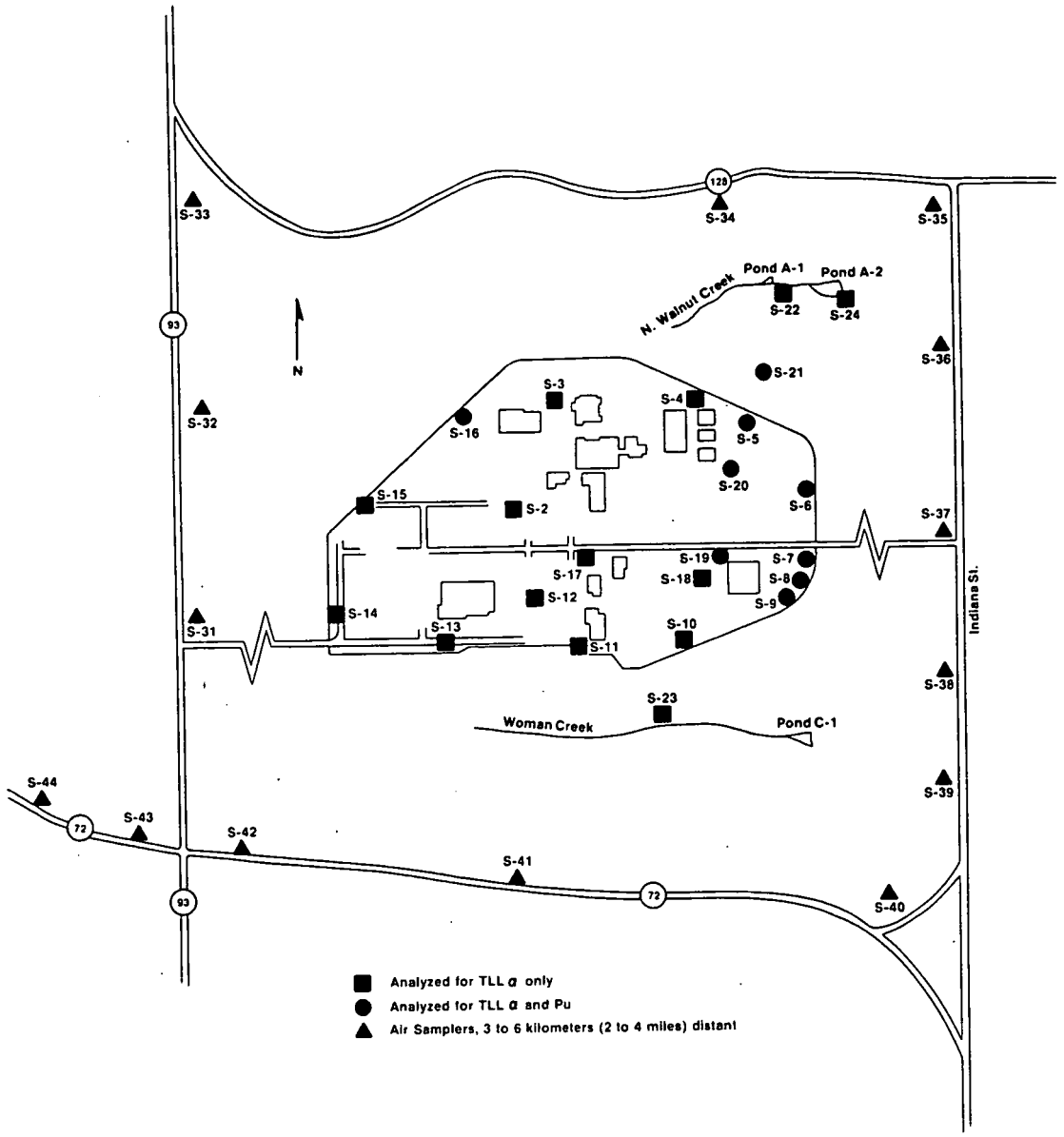

FIGURE 6. Location of Onsite and Plant Perimeter Ambient Air Samplers
(Portions of figure are not to scale.)

Samples of airborne particulates are collected on filters by high-volume air samplers at 14 locations along or near the Plant perimeter. These perimeter samplers are located between 3 and 6 km (2 and 4 mi) from the Plant center. (See Figure 6). The samplers are numbered S-31 through S-44. Samples from each location are collected weekly, composited by location, and analyzed for a four-week period for plutonium. Table 7 presents the average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1981. The average concentration of plutonium in ambient air at these locations during 1981 was 6.66×10^{-7} Bq/m^3 (0.018×10^{-15} μCi/mℓ). This concentration was 0.09 percent of the soluble plutonium RCG_a for the general population.[2, 4]

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TABLE 5. Plutonium-239 and -240 Concentrations in Onsite Ambient Air at Selected Locations[a]

Station	Number of Analyses	Volume (X 1000 m^3)	Concentration[b] (X 10^{-15} μCi/mℓ) C_{min}[c] LCL[d]	C_{min} Point Estimate	C_{min} UCL[e]	C_{max}[c] LCL	C_{max} Point Estimate	C_{max} UCL	C_{avg}[c] LCL	C_{avg} Point Estimate	C_{avg} UCL	Percent of RCG_a[f]
S-5	27	417	(0.043)	0.050	(0.058)	(0.326)	0.365	(0.411)	(0.100)	0.104	(0.108)	0.17
S-6	27	428	(0.038)	0.044	(0.051)	(0.130)	0.147	(0.167)	(0.092)	0.095	(0.099)	0.16
S-7	27	355	(0.120)	0.139	(0.162)	(0.701)	0.782	(0.880)	(0.277)	0.289	(0.300)	0.48
S-8	27	455	(0.093)	0.105	(0.118)	(1.843)	2.032	(2.265)	(0.387)	0.398	(0.410)	0.66
S-9	27	414	(0.255)	0.284	(0.319)	(1.052)	1.166	(1.303)	(0.531)	0.549	(0.567)	0.92
S-16	27	418	(0.002)	0.005	(0.007)	(0.042)	0.050	(0.060)	(0.025)	0.027	(0.028)	0.05
S-19	27	418	(0.015)	0.020	(0.025)	(0.099)	0.124	(0.150)	(0.070)	0.074	(0.078)	0.12
S-20	27	394	(0.013)	0.016	(0.020)	(0.431)	0.482	(0.546)	(0.064)	0.069	(0.074)	0.12
S-21	27	444	(0.008)	0.011	(0.015)	(0.194)	0.221	(0.253)	(0.051)	0.054	(0.057)	0.09

a. These selected air-sampling locations are in the proximity of areas where potential for airborne radioactivity exists (see Figure 6).
b. Two-week composites of station concentrations.
c. C_{min} = Minimum measured concentration; C_{max} = Maximum measured concentration; C_{avg} = Average measured concentration.
d. LCL = Lower Confidence Limit.
e. UCL = Upper Confidence Limit.
f. The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air in uncontrolled areas is 60 X 10^{-15} μCi/mℓ.

TABLE 6. Tritium Activity Concentrations in Onsite Ambient Air Water Vapor

Station	Number of Analyses	Concentration (X 10^{-9} μCi/mℓ) C_{min}	C_{max}	C_{avg}[a]	Percent of RCG_w[b]
S-4	48	-150 ± 700	600 ± 450	< 300 ± 450	< 0.03
S-5	42	0 ± 250	450 ± 450	< 400 ± 400	< 0.04
S-16	47	-150 ± 450	500 ± 450	< 200 ± 400	< 0.02

a. The average tritium concentrations are less than 2.0 percent of the State of Colorado primary drinking water limit of 20,000 X 10^{-9} μCi/mℓ.
b. The Radioactivity Concentration Guide (RCG_w) for tritium in water released to uncontrolled areas is 1,000,000 X 10^{-9} μCi/mℓ.

Samples of airborne particulates are also collected at nine locations in or near communities in the vicinity of the Rocky Flats Plant. These locations, as identified in Figure 7, are Boulder, Broomfield, Denver, Golden, Lafayette, Leyden, Superior, Wagner, and Westminster. Sample filters are collected weekly, composited by location, and analyzed for a four-week period for plutonium radioactivity.

Table 8 presents the average concentrations of plutonium in airborne particulates at the community stations during 1981. The average concentration of plutonium in ambient air at the community stations was 7.03 X 10^{-7} Bq/m^3 (0.019 X 10^{-15} μCi/mℓ). This value is 0.10 percent of the soluble plutonium RCG_a for the general population.[2,4]

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TABLE 7. Plutonium-239 and -240 Activity Concentrations in Perimeter Ambient Air

Station	Number of Analyses	Volume (X 1000 m³)	Concentration (X 10^{-15} μCi/mℓ) C_{min} LCL	C_{min} Point Estimate	C_{min} UCL	C_{max} LCL	C_{max} Point Estimate	C_{max} UCL	C_{avg} LCL	C_{avg} Point Estimate	C_{avg} UCL	Percent[a] of RCG_a
S-31	12	412	(0.000)	0.002	(0.004)	(0.037)	0.042	(0.050)	(0.016)	0.018	(0.019)	0.10
S-32	12	431	(–)[b]	0.004	(–)[b]	(–)[b]	0.054	(–)[b]	(–)[b]	0.023	(–)[b]	0.11
S-33	12	419	(0.001)	0.003	(0.006)	(0.033)	0.038	(0.044)	(0.015)	0.017	(0.019)	0.10
S-34	12	461	(0.002)	0.004	(0.006)	(0.034)	0.039	(0.046)	(0.015)	0.016	(0.017)	0.09
S-35	12	430	(0.001)	0.002	(0.004)	(0.041)	0.047	(0.056)	(0.017)	0.019	(0.020)	0.10
S-36	12	437	(0.008)	0.002	(0.011)	(0.037)	0.043	(0.050)	(0.016)	0.018	(0.020)	0.10
S-37	12	457	(0.003)	0.005	(0.008)	(0.037)	0.043	(0.050)	(0.019)	0.021	(0.022)	0.10
S-38	12	413	(0.003)	0.006	(0.009)	(0.051)	0.062	(0.075)	(0.020)	0.022	(0.024)	0.11
S-39	12	435	(0.001)	0.004	(0.006)	(0.035)	0.041	(0.048)	(0.016)	0.017	(0.018)	0.10
S-40	12	455	(0.000)	0.002	(0.005)	(0.036)	0.047	(0.061)	(0.016)	0.017	(0.018)	0.10
S-41	12	438	(0.001)	0.003	(0.005)	(0.039)	0.046	(0.054)	(0.017)	0.018	(0.020)	0.10
S-42	12	397	(0.001)	0.003	(0.004)	(0.067)	0.087	(0.110)	(0.020)	0.022	(0.024)	0.11
S-43	12	436	(0.000)	0.002	(0.003)	(0.039)	0.046	(0.055)	(0.015)	0.016	(0.018)	0.09
S-44	12	451	(0.001)	0.003	(0.004)	(0.035)	0.043	(0.053)	(0.016)	0.017	(0.018)	0.10
Summary	168	–	–	0.002	–	–	0.054	–	–	–	–	–
Average Concentration		–	–	–	–	–	–	–	–	0.018	–	0.10

a. The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air available to the general population is 20 X 10^{-15} μCi/mℓ.
b. Air flow calibration data required for LCL, UCL calculations were not available.

C. Nonradioactive Ambient Air Monitoring

During 1981, limited monitoring of ambient air for total suspended particulates (TSP) and ozone (O_3) was conducted, utilizing instrumentation in a self-contained van for mobile ambient air monitoring (MAAM). The TSP and O_3 concentrations in ambient air are regulated by the EPA through the Clean Air Act of 1970, including the National Ambient Air Quality Standards (NAAQS).[6] Table 9 gives the detection methods and operating ranges of the MAAM monitoring instrumentation with corresponding compliance standards.

During 1981, the van remained stationary at a location near the east entrance to the Plant. This is an open area that is near a traffic zone and is generally downwind from Plant buildings. Ambient air data were collected during the last quarter of the year and are presented in Table 10.

Total suspended particulate measurements using the EPA Reference Hi-Vol Method were initiated in October 1981. The sampler was located on top of the MAAM van and was operated on the EPA once-every-sixth day sampling schedule. The highest value recorded (a 24-hour sample) was 104 μg/m³ during early October and was believed to have been heavily biased by nearby construction activities. Extensive earth moving and road grading in the area released fugitive dust into the air during this sampling period. The calculated geometric mean for the fourth quarter of TSP data, 33 μg/m³, is believed to be an accurate representation of particulate levels surrounding the Rocky Flats Plant. The Colorado Department of Health routinely performs TSP measurements at the Plant boundary. Historically these measurements have shown annual average particulate levels ranging from about 30 to 66 μg/m³, which are well below the NAAQS.

The chemiluminescent O_3 analyzer was calibrated by use of a Secondary UV Photometer standard,

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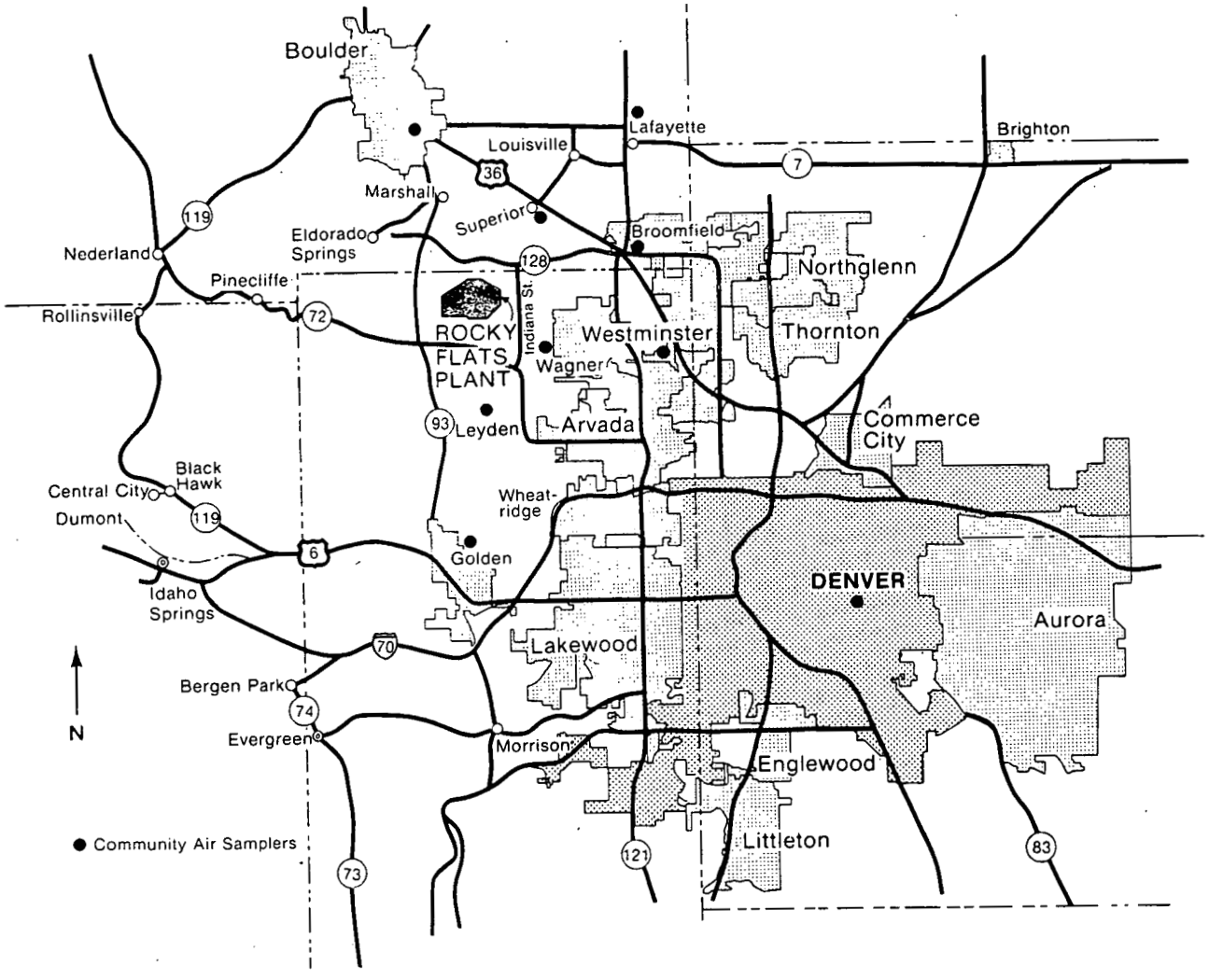

FIGURE 7. Location of Community Ambient Air Samplers

with traceability to an EPA Primary UV Photometer. These data were assessed with an accuracy of ± 10 percent based on the weekly performance of zero and span checks. The number of data points reported are not sufficient for direct comparisons to annual NAAQS; however, the data can be used as a general indicator of air quality in this section of Colorado's Air Quality Control Region 3. The highest observed hourly average for O_3, during the fourth quarter of sampling was 0.070 ppm. The O_3 standard was not violated.

D. Waterborne Effluent Monitoring

North Walnut Creek receives storm water runoff from the north side of the Plant site. (See Figure 3.) Holding Pond A-3 on North Walnut Creek is used to impound this surface runoff for analysis prior to discharge. A second control point, holding Pond A-4, is located further downstream.

Ponds A-1 and A-2 are isolated from North Walnut Creek. In the past, these ponds have been used for storage and evaporation of laundry water. This practice was discontinued during 1980. Disposition of Pond A-1 and A-2 water is through natural evaporation and is enhanced by spraying water through fog nozzles over the surface of the ponds. Excess water that does not evaporate is then recollected by the ponds. Typically the plutonium concentration in this water averages less than 0.2 Bq/ℓ (5×10^{-9} μCi/mℓ).

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TABLE 8. Plutonium-239 and -240 Activity Concentrations in Community Ambient Air

Station	Number of Analyses	Volume (X 1000 m³)	Concentration (X 10^{-15} μCi/mℓ) C_{min} LCL	C_{min} Point Estimate	C_{min} UCL	C_{max} UCL	C_{max} Point Estimate	C_{max} UCL	C_{avg} LCL	C_{avg} Point Estimate	C_{avg} UCL	Percent* of RCG_a
Superior	12	447	(0.000)	0.002	(0.004)	(0.034)	0.048	(0.064)	(0.017)	0.019	(0.020)	0.10
Boulder	12	435	(0.000)	0.002	(0.003)	(0.192)	0.224	(0.266)	(0.028)	0.030	(0.032)	0.16
Lafayette	12	430	(0.001)	0.002	(0.004)	(0.040)	0.049	(0.061)	(0.016)	0.018	(0.020)	0.10
Broomfield	12	387	(0.001)	0.003	(0.006)	(0.034)	0.043	(0.053)	(0.017)	0.019	(0.020)	0.10
Wagner	12	426	(0.002)	0.000	(0.002)	(0.033)	0.044	(0.056)	(0.015)	0.016	(0.018)	0.09
Leyden	12	446	(0.001)	0.003	(0.004)	(0.057)	0.068	(0.082)	(0.017)	0.018	(0.020)	0.10
Westminster	12	373	(0.000)	0.002	(0.004)	(0.023)	0.031	(0.041)	(0.011)	0.012	(0.014)	0.06
Denver	12	429	(0.001)	0.003	(0.005)	(0.027)	0.035	(0.043)	(0.013)	0.014	(0.016)	0.07
Golden	12	427	(0.000)	0.001	(0.003)	(0.035)	0.043	(0.053)	(0.016)	0.017	(0.018)	0.10
Summary	108	–	–	0.001	–	–	0.224	–	–	–	–	–
Average Concentration		–	–	–	–	–	–	–	–	0.019	–	0.10

*The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air available to the general population is 20 X 10^{-15} μCi/mℓ.

TABLE 9. Mobile Ambient Air Monitoring (MAAM) Van Detection Methods and National Air Quality Standards (NAAQS) for Total Suspended Particulates and Ozone

Parameter	Detection Methods and Analyzer Ranges	NAAQS Averaging Time	Concentration
Total Suspended Particulates (TSP)	Reference Method (Hi Volume) 24-hour sampling (6th-day scheduling)	Annual Geometric Mean: Primary[a]	75 μg/m³
		Secondary[b]	60 μg/m³
		24-hour Primary[a, c]	260 μg/m³
		Secondary[b, c]	150 μg/m³
Ozone (O_3)	Beckman Model 950 Chemiluminescent 0–0.5 ppm	1 hour Primary[a, d]	0.12 ppm

a. Primary NAAQS are intended to protect public health.
b. Secondary NAAQS are intended to protect public welfare.
c. Not to be exceeded more than once per year.
d. Statistically estimated number of days with concentrations in excess of the standard is not to be more than 1.0 per year.

South Walnut Creek receives storm water runoff from the central portion of the Plant. This water is diverted through a culvert system to Pond B-4 and then to Pond B-5 where the water is impounded for analysis prior to controlled offsite discharge.

In the past, treated sanitary wastewater was also discharged to South Walnut Creek. This practice was discontinued in 1979. During 1981, some treated sanitary wastewater was recycled through the Plant reverse osmosis facility for further treatment and was reused in Plant cooling towers.

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TABLE 10. Onsite MAAM Van Ambient Air Quality Data (Nonradioactive)
(Fourth Quarter, October - December 1981)

Total Suspended Particulates ($\mu g/m^3$)	
Total Number of Samples	17
Geometric Mean	33
Observed 24-Hour Maximum	104*
Second Highest Maximum	73
Lowest Observed Value	18
Ozone (ppm)	
Number of Observations, Hourly	1492
Arithmetic Mean	0.030
Maximum 1-Hour Concentration	0.070
Second Highest 1-Hour Concentration	0.065
Minimum Observation	0.002

*Observed construction activities near sampling location believed to have biased sample.

Excess water that could not be recycled was discharged directly to Pond B-3 and was spray-irrigated onto Rocky Flats soil. Ponds B-1 and B-2, also located in the central drainage, are reserved as backup control ponds. These ponds can be used to retain either surface water runoff or treated sanitary wastewater of questionable quality.

Surface runoff water from the south side of the Plant is collected in an interceptor ditch and flows to surface water control Pond C-2, where the water is impounded and analyzed before discharge to offsite receiving waters. Woman Creek, also in the south drainage, is isolated from this system. Pond C-1 is used as a monitoring point for Woman Creek.

Discharges from the Rocky Flats Plant are monitored for compliance with appropriate Colorado Department of Health standards and EPA NPDES permit limitations.[7] Annual average concentrations of chemical and biological constituents of liquid effluent samples collected from Ponds A-3, A-4, B-5, C-1, and C-2 during 1981 are presented in Table 11. The data are indicative of overall water quality from those ponds.

On May 20, 1981, the NPDES permit with four discharge locations - 001, 002, 003, and 004 expired and was replaced by a new NPDES permit with seven discharge locations - 001, 002, 003, 004, 005, 006, and 007. Each discharge location is identified in Table 11. The NPDES permit places monitoring and reporting requirements and limitations on daily concentrations and monthly average concentrations for some specific parameters. There were no violations of the NPDES permit during 1981.

Prior to discharge from Ponds A-4, B-5, and C-2, water is sampled and analyzed for gross alpha, gross beta, tritium, gamma activity, pH, nitrate as N, and nonvolatile suspended solids. The water will not be discharged if the Plant action level for any parameter is exceeded.

During planned discharges from Ponds A-4, B-5, and C-2 in 1981, the water was sampled continuously. The samples were analyzed for plutonium, uranium, americium, and tritium. Water was also sampled continuously and collected daily from the outfall of Pond C-1 and collected from the Walnut Creek at Indiana Street sampling station when there was sufficient flow. Daily

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TABLE 11. Annual Average Concentrations of Chemical and Biological Constituents in Liquid Effluents[a]

Parameter	Number of Analyses	C_{min}	C_{max}	C_{avg}
Discharge 001[b]				
During 1981, no discharges were made to offsite waters.				
Discharge 002[b]				
pH, SU[c]	10	6.4	8.3	7.7
Nitrate as N, mg/ℓ	10	3.3	8.3	6.0
Discharge 003[b, d]				
pH, SU	9	7.5	8.9	7.9
Nitrate as N, mg/ℓ	4	< 0.2	0.2	< 0.2
Total Dissolved Solids, mg/ℓ	9	115	279	197
Chemical Oxygen Demand, mg/ℓ	4	8.0	18.0	12.3
Discharge 004[b]				
During 1981, no discharges were made to offsite waters				
Discharge 005[b]				
pH, SU	9	7.3	8.7	7.7
Nitrate as N, mg/ℓ	9	2.4	12.7	5.2
Nonvolatile Suspended Solids, mg/ℓ	9	5	190	43
Discharge 006[b]				
pH, SU	12	7.6	8.5	8.0
Nitrate as N, mg/ℓ	12	0.4	5.6	< 1.4
Nonvolatile Suspended Solids, mg/ℓ	12	< 4	687	< 142
Discharge 007[b]				
pH, SU	4	7.6	8.0	7.8
Nitrate as N, mg/ℓ	4	< 1	2.5	< 1.3
Nonvolatile Suspended Solids, mg/ℓ	4	2	26	14

a. Examples of NPDES Permit limitations are presented in Table 26.
b. The Environmental Protection Agency NPDES discharge permit defines the discharge locations as follows:
001 - Sewage treatment plant prior to May 20, 1981; Pond B-3 thereafter
002 - Pond A-3
003 - Pond C-1 prior to May 20, 1981; reverse osmosis pilot plant thereafter
004 - Reverse Osmosis Plant
005 - Pond A-4
006 - Pond B-5
007 - Pond C-2
c. SU - Standard Unit.
d. These analytical results were determined prior to May 20, 1981.

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samples were composited into weekly samples for plutonium, uranium, and americium analyses. Once each week, daily samples at Pond C-1 and Walnut Creek at Indiana were analyzed for tritium. Concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, B-5, C-1, C-2, and from Walnut Creek at Indiana Street are presented in Tables 12 and 13. All plutonium, uranium, americium, and tritium concentrations at these locations were 3.8 percent or less of the applicable Radioactivity Concentration Guides (RCG_W).[2, 4]

The Rocky Flats Plant water supply was taken from two sources during the year—Ralston Reservoir and South Boulder Diversion Canal. Ralston

TABLE 12. Plutonium, Uranium, and Americium Concentrations at the Rocky Flats Plant

Location	Number of Analyses	C_{min}	C_{max}	C_{avg}	Percent of RCG_W
		Plutonium Concentration ($\times 10^{-9}$ μCi/mℓ)[a]			
Pond A-4	6	0.04 ± 0.02	0.10 ± 0.05	0.08 ± 0.02	0.005
Pond B-5	11	0.00 ± 0.01	0.15 ± 0.07	0.04 ± 0.01	0.002
Pond C-1	37	−0.002 ± 0.007	0.22 ± 0.04	0.029 ± 0.002	0.002
Pond C-2	3	0.03 ± 0.03	0.05 ± 0.02	0.04 ± 0.02	0.002
Walnut Creek at Indiana St.	22	0.00 ± 0.01	0.07 ± 0.04	0.020 ± 0.004	0.001
		Uranium Concentration ($\times 10^{-9}$ μCi/mℓ)[b]			
Pond A-4	6	2.0 ± 0.4	11.5 ± 0.6	5.3 ± 0.2	2.7
Pond B-5	11	0.7 ± 0.1	6.8 ± 0.2	4.6 ± 0.1	2.3
Pond C-1	37	−0.7 ± 0.06	6.5 ± 0.2	2.23 ± 0.03	1.1
Pond C-2	3	1.8 ± 0.2	4.3 ± 0.1	3.0 ± 0.1	1.5
Walnut Creek at Indiana St.	22	1.2 ± 0.1	11.9 ± 0.3	7.6 ± 0.1	3.8
		Americium Concentration ($\times 10^{-9}$ μCi/mℓ)[c]			
Pond A-4	6	0.00 ± 0.01	0.10 ± 0.05	0.03 ± 0.02	0.002
Pond B-5	11	−0.02 ± 0.02	0.14 ± 0.05	0.02 ± 0.01	0.002
Pond C-1	37	−0.01 ± 0.02	0.05 ± 0.02	0.004 ± 0.002	0.0003
Pond C-2	3	0.00 ± 0.04	0.05 ± 0.03	0.02 ± 0.02	0.002
Walnut Creek at Indiana St.	22	−0.01 ± 0.03	0.08 ± 0.07	0.010 ± 0.004	0.001

a. Radiochemically determined as plutonium-239 and -240. The Radioactivity Concentration Guide (RCG_W) for soluble plutonium in water is 1667×10^{-9} μCi/mℓ.
b. Radiochemically determined as uranium-233, -234, and -238. The most restrictive RCG_W for these uranium isotopes in the soluble form is 200×10^{-9} μCi/mℓ.
c. Radiochemically determined as americium-241. The RCG_W for soluble americium-241 is 1330×10^{-9} μCi/mℓ.

TABLE 13. Tritium Concentrations at the Rocky Flats Plant

Location	Number of Analyses	Tritium Concentration ($\times 10^{-9}$ μCi/mℓ) C_{min}	C_{max}	C_{avg}	Percent of RCG_W*
Pond A-4	7	−200 ± 400	1200 ± 500	400 ± 200	0.04
Pond B-5	14	0 ± 500	800 ± 400	400 ± 100	0.04
Pond C-1	37	−500 ± 500	900 ± 500	< 400	< 0.04
Pond C-2	5	100 ± 400	400 ± 600	200 ± 200	0.02
Walnut Creek at Indiana St.	24	−300 ± 500	1000 ± 500	400 ± 100	0.04

*The Radioactivity Concentration Guide (RCG_W) for tritium in water released to uncontrolled areas is $1{,}000{,}000 \times 10^{-9}$ μCi/mℓ.

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Reservoir is located near the Schwartzwalder uranium mine and the water usually contains more uranium activity than does water from the South Boulder Diversion Canal, which flows from the Moffat Tunnel. Throughout the year, weekly uranium analyses were performed on samples of Rocky Flats raw and treated water. Uranium concentrations measured during 1981 are presented in Table 14. Uranium concentrations measured during 1981 in raw and treated water averaged 0.10 and 0.074 Bq/ℓ (2.8×10^{-9} and 2.0×10^{-9} μCi/mℓ), respectively. That water was used throughout the Plant, discharged to the sanitary sewage system, and ultimately spray-irrigated from Pond B-3 or reused in Plant cooling towers.

Biocides and herbicides are used in pest and weed control on the Rocky Flats Plant site, and water samples are collected from Ponds B-4 and C-1 during the period of application. Analytical results for 2,4-D and Bromacil have consistently been less than 2 parts per billion (ppb). The recommended concentration limit is 100 ppb.

Polychlorinated biphenyls (PCB's) are stored at the Rocky Flats Plant and are present in some transformer oils, each in accordance with EPA guidance. Analytical results from downstream waters during 1981 showed no detectable concentrations of PCB's above a detectable concentration of approximately 1 ppb.

E. Groundwater Monitoring

Groundwater occurs in the Rocky Flats alluvium, Arapahoe Formation, and the Laramie-Fox Hills aquifer. (See Figure 8.) The Rocky Flats alluvium consists primarily of clay, silt, sand, and gravel. The Arapahoe Formation consists of sand and clay. The Laramie Formation is divisible into two units—a lower sandstone unit and an upper shale unit. The lower sandstone unit, together with the Fox Hills Sandstone, are collectively referred to as the Laramie-Fox Hills aquifer.

In March, August, and November, 49 groundwater monitoring wells (shown in Figure 9) were checked for water. Samples from monitoring wells containing water were analyzed to determine significant movement of chemical or radioactive materials of possible Plant origin into water-bearing strata underlying the site.

Five of the monitoring wells range from 43 to 96 meters (140 to 320 feet) in depth. These monitoring wells, numbered 1-66, 2-66, 3-66, 21-74, and 22-74, are located, respectively, west of the west security fence, northeast of the solar ponds, east of the solar ponds, near the south security fence and east of the east security fence. These wells provide information concerning water quality in gravel and bedrock formations.

TABLE 14. Uranium Concentrations in Rocky Flats Raw and Treated Water

Location	Number of Analyses	C_{min}[a]	C_{max}[a]	C_{avg}[a]
		Raw Water		
Ralston Reservoir[b]	14	1.1 ± 0.1	14.1 ± 0.7	6.7 ± 0.1
South Boulder Diversion Canal[b]	32	0.13 ± 0.05	4.8 ± 0.2	1.17 ± 0.02
Summary	46	–	–	2.85 ± 0.03
		Treated Water		
Ralston Reservoir[b]	14	0.2 ± 0.1	7.5 ± 0.4	3.7 ± 0.1
South Boulder Diversion Canal[b]	32	0.1 ± 0.1	7.8 ± 0.4	1.27 ± 0.04
Summary	46	–	–	2.01 ± 0.04

a. Uranium concentration ($\times 10^{-9}$ μCi/mℓ). Radiochemically determined as uranium-233, -234, and -238.
b. Sampled at the Rocky Flats water treatment plant.

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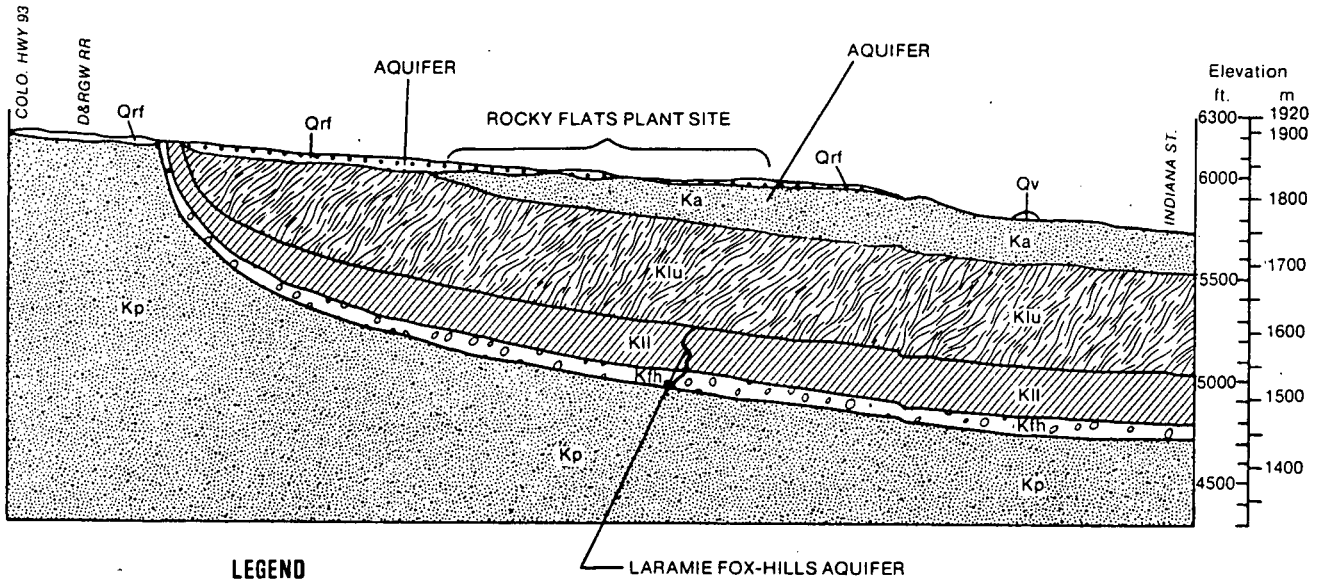
FIGURE 8. Geologic Cross-Section in the Rocky Flats Plant Area



LEGEND

- Qv VERDOS ALLUVIUM
- Qrf ROCKY FLATS ALLUVIUM
- Ka ARAPAHOE FORMATION
- Klu UPPER LARAMIE FORMATION
- Kll LOWER LARAMIE FORMATION
- Kfh FOX HILLS SANDSTONE
- Kp PIERRE SHALE

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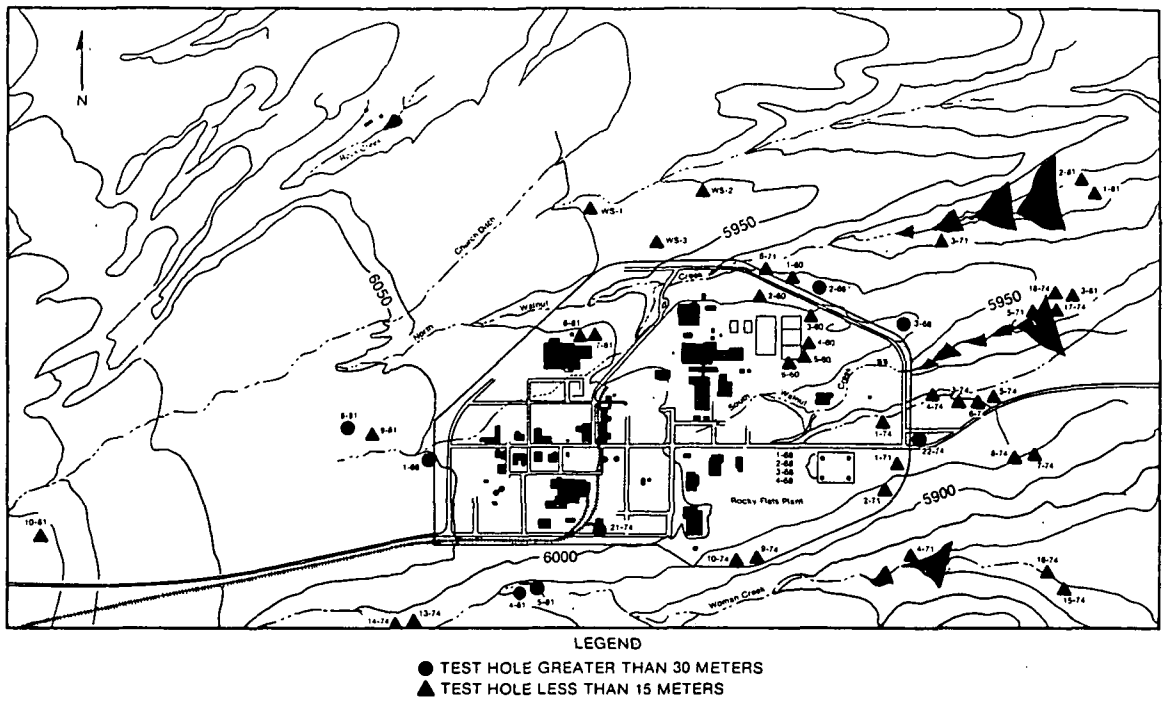

FIGURE 9. Location of Groundwater Monitoring Wells

Ten new monitoring wells were drilled in 1981. Three of those wells, 1-81, 2-81, and 3-81, are approximately 6 m (20 ft) deep and were drilled to monitor groundwater near holding ponds and drainage areas. Monitoring Wells 4-81 and 5-81 are 1 m (4 ft) and 6 m (20 ft) deep, respectively. These monitoring wells were drilled to replace Monitoring Wells 11-74 and 12-74, which were abandoned during the year. Monitoring Wells 6-81 and 7-81 are both 9 m (30 ft) deep and were drilled to monitor groundwater near an underground fuel tank. Monitoring Wells 8-81, 9-81, and 10-81 range from 9 m (30 ft) to 30 m (100 ft) deep and were drilled to monitor groundwater near a spray irrigation site.

Due to construction of the Plant's new Perimeter Security Zone (PSZ), some of the monitoring wells were modified. The pipe for Monitoring Well 1-60 was extended 3 m (9 ft) and the pipe for Monitoring Well 6-71 was extended 1 m (3 ft). The pipe for Monitoring Well 2-66 was cut off by approximately 0.3 m (1 ft). Because of the change in ground elevation, Monitoring Well 2-74 was abandoned.

The remaining wells range from 1 to 15 m (3 to 50 ft) deep and generally are located near three onsite solar evaporation ponds, other holding ponds, and old trash burial sites.

Water samples from the monitoring wells were analyzed for plutonium, uranium, americium, and tritium. Tables 15 and 16 present measured depths of the monitoring wells and radioactivity concentrations for water obtained from each monitoring well during 1981. Sampling of the 10 new monitoring wells, drilled in March of 1981, began in August.

Tritium and/or uranium have been detected at low concentrations in monitoring wells close to solar evaporation ponds that have been used to store process wastewater prior to treatment. These ponds are hydrologically upgradient from the monitoring wells and some seepage has occurred.

Water from monitoring wells 9-74, 10-74, 15-74, 17-74, and 18-74 had uranium concentrations slightly higher than regional background. The uranium concentrations are consistent with the

TABLE 15. Plutonium and Americium Concentrations in Groundwater Monitoring Wells

Location Number	Depth (meters)	Plutonium Concentration[a] ($\times 10^{-9}$ µCi/mℓ)			Americium Concentration[b] ($\times 10^{-9}$ µCi/mℓ)		
		March	August	November	March	August	November
1-60	6	0.022 ± 0.069	-0.013 ± 0.052	0.134 ± 0.198	-0.009 ± 0.017	0.211 ± 0.075	0.140 ± 0.159
2-60	7	0.001 ± 0.048	N/A	0.001 ± 0.089	0.002 ± 0.023	-0.004 ± 0.046	-0.069 ± 0.083
3-60	9	-0.005 ± 0.016	-0.020 ± 0.020	-0.017 ± 0.031	0.004 ± 0.019	-0.027 ± 0.032	0.063 ± 0.049
4-60	9	-0.003 ± 0.029	-0.004 ± 0.028	0.096 ± 0.066	0.006 ± 0.021	-0.032 ± 0.035	0.065 ± 0.051
5-60	9	Dry	Dry	Dry	Dry	Dry	Dry
6-60	9	0.000 ± 0.014	-0.011 ± 0.022	-0.016 ± 0.043	-0.003 ± 0.017	-0.038 ± 0.038	-0.008 ± 0.064
1-66	45	0.003 ± 0.016	0.033 ± 0.046	0.001 ± 0.027	-0.004 ± 0.017	-0.031 ± 0.033	0.058 ± 0.053
2-66	43	-0.007 ± 0.015	-0.019 ± 0.026	-0.038 ± 0.026	0.000 ± 0.018	-0.036 ± 0.036	0.004 ± 0.031
3-66	47	-0.003 ± 0.015	0.038 ± 0.030	0.133 ± 0.089	-0.002 ± 0.018	0.208 ± 0.066	0.004 ± 0.056
1-68	1	Dry	Dry	Dry	Dry	Dry	Dry
2-68	1	Dry	Dry	Dry	Dry	Dry	Dry
3-68	1	Dry	Dry	Dry	Dry	Dry	Dry
4-68	1	Dry	Dry	Dry	Dry	Dry	Dry
1-71	9	0.002 ± 0.013	0.003 ± 0.023	-0.040 ± 0.023	-0.009 ± 0.018	-0.011 ± 0.030	-0.029 ± 0.053
2-71	9	0.001 ± 0.014	-0.016 ± 0.021	0.033 ± 0.055	0.009 ± 0.021	-0.014 ± 0.040	-0.011 ± 0.042
3-71	8	-0.010 ± 0.013	-0.002 ± 0.025	-0.037 ± 0.049	-0.021 ± 0.018	-0.027 ± 0.048	-0.021 ± 0.026
4-71	7	0.000 ± 0.017	-0.012 ± 0.020	0.036 ± 0.040	0.001 ± 0.027	-0.020 ± 0.034	0.011 ± 0.051
5-71	9	-0.003 ± 0.014	Dry	Dry	0.002 ± 0.020	Dry	Dry
6-71	9	0.000 ± 0.015	-0.013 ± 0.024	-0.033 ± 0.031	-0.008 ± 0.017	0.003 ± 0.064	0.000 ± 0.041
1-74	7	0.007 ± 0.017	-0.012 ± 0.022	-0.008 ± 0.029	-0.007 ± 0.016	-0.020 ± 0.052	-0.049 ± 0.032
2-74	3	Dry	Dry	N/A[c]	Dry	Dry	N/A
3-74	7	Dry	-0.016 ± 0.024	Dry	Dry	-0.043 ± 0.037	Dry
4-74	2	Dry	Dry	Dry	Dry	Dry	Dry
5-74	5	Dry	Dry	Dry	Dry	Dry	Dry
6-74	2	Dry	Dry	Dry	Dry	Dry	Dry
7-74	15	0.010 ± 0.024	0.017 ± 0.026	0.101 ± 0.071	-0.008 ± 0.016	0.002 ± 0.033	0.030 ± 0.048
8-74	12	Dry	Dry	Dry	Dry	Dry	Dry
9-74	6	0.009 ± 0.019	0.019 ± 0.030	-0.075 ± 0.077	-0.008 ± 0.018	0.012 ± 0.035	0.037 ± 0.086
10-74	3	0.002 ± 0.013	0.019 ± 0.026	Dry	-0.002 ± 0.023	0.060 ± 0.049	Dry
11-74	6	Dry	Dry	N/A	Dry	Dry	N/A
12-74	1	-0.004 ± 0.013	Dry	N/A	0.006 ± 0.020	Dry	N/A
13-74	6	0.031 ± 0.015	-0.022 ± 0.018	0.018 ± 0.054	-0.010 ± 0.038	-0.037 ± 0.048	0.080 ± 0.061
14-74	1	Dry	Dry	Dry	Dry	Dry	Dry
15-74	6	0.023 ± 0.021	0.014 ± 0.043	-0.033 ± 0.022	-0.008 ± 0.016	-0.023 ± 0.039	-0.003 ± 0.057
16-74	1	Dry	Dry	Dry	Dry	Dry	Dry
17-74	5	0.003 ± 0.019	-0.012 ± 0.025	0.032 ± 0.046	-0.008 ± 0.018	-0.037 ± 0.032	0.010 ± 0.055
18-74	2	0.002 ± 0.017	Dry	Dry	-0.002 ± 0.018	Dry	Dry
21-74	81	-0.001 ± 0.016	0.010 ± 0.026	-0.012 ± 0.027	0.004 ± 0.020	-0.055 ± 0.037	-0.004 ± 0.065
22-74	96	0.014 ± 0.020	0.008 ± 0.024	-0.045 ± 0.049	-0.008 ± 0.015	-0.035 ± 0.041	0.014 ± 0.045
WS-1	4	Dry	-0.022 ± 0.018	0.018 ± 0.041	Dry	-0.026 ± 0.035	0.012 ± 0.050
WS-2	3	-0.001 ± 0.015	-0.021 ± 0.023	Dry	-0.004 ± 0.017	-0.034 ± 0.033	Dry
WS-3	4	-0.001 ± 0.015	0.004 ± 0.026	0.135 ± 0.063	-0.010 ± 0.014	-0.035 ± 0.036	0.069 ± 0.055
1-81	6	–	-0.019 ± 0.020	0.009 ± 0.040	–	-0.056 ± 0.034	0.138 ± 0.101
2-81	6	–	-0.012 ± 0.029	-0.001 ± 0.019	–	-0.026 ± 0.034	-0.015 ± 0.046
3-81	6	–	-0.012 ± 0.025	0.005 ± 0.044	–	-0.040 ± 0.038	0.045 ± 0.033
4-81	1	–	Dry	Dry	–	Dry	Dry
5-81	6	–	-0.004 ± 0.023	-0.035 ± 0.025	–	-0.015 ± 0.039	-0.031 ± 0.038
6-81	9	–	-0.001 ± 0.027	-0.042 ± 0.034	–	-0.024 ± 0.035	-0.003 ± 0.046
7-81	9	–	-0.021 ± 0.021	-0.042 ± 0.034	–	-0.047 ± 0.033	-0.003 ± 0.046
8-81	30	–	0.002 ± 0.024	0.075 ± 0.073	–	-0.038 ± 0.035	0.057 ± 0.052
9-81	9	–	-0.015 ± 0.021	-0.006 ± 0.029	–	-0.031 ± 0.037	0.075 ± 0.051
10-81	9	–	-0.018 ± 0.020	0.011 ± 0.038	–	-0.020 ± 0.036	0.070 ± 0.070

a. Radiochemically determined as plutonium-239, -240.
b. Radiochemically determined as americium-241.
c. N/A - Not analyzed.

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8-81	30	–	-0.1 ± 0.1	0.0 ± 0.0	–	1481 ± 453	-252 ± 515
9-81	9	–	0.0 ± 0.1	0.1 ± 0.1	–	463 ± 457	76 ± 561
10-81	9	–	-0.1 ± 0.1	0.4 ± 0.1	–	251 ± 406	-551 ± 600

a. Radiochemically determined as uranium-233, -234, and -238.
b. N/A - Not analyzed.

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historical data on these monitoring wells. The uranium may be natural material and not of Rocky Flats Plant origin. Small pockets of low grade uranium ore are not uncommon in the Arapahoe bedrock formation, which underlies the Plant.

There are no applicable RCG's for groundwater; however, for perspective, the concentrations of plutonium, uranium, americium, and tritium in all samples were well below the DOE and Colorado Department of Health RCG's for water discharged to uncontrolled areas.[2,4]

F. Regional Water Monitoring

Regional water monitoring includes sampling and analysis of public water supplies and tap water from several surrounding communities. Of the regional water supplies, only Great Western Reservoir and Standley Lake receive runoff from Rocky Flats drainage systems (Figure 3). The Rocky Flats contributions to radionuclides in regional water supplies through airborne emissions were estimated in the Rocky Flats Environmental Impact Statement.[1] These contributions were insignificant compared to contributions from fallout and natural background.

Water samples were collected weekly from Great Western Reservoir, a water supply for the city of Broomfield, and from Standley Lake, a water supply for the city of Westminster and portions of the cities of Thornton and Northglenn. The weekly samples were composited into a monthly sample, and analyses were performed for plutonium, uranium, and americium concentrations. Tritium analysis was conducted for each weekly sample. Annual grab samples were also collected from three additional regional reservoirs (Ralston, Dillon, and Boulder) and one stream (South Boulder Diversion Canal) at distances ranging from 1.6 to 96 km (1 to 60 mi) from the Plant. These samples were collected to determine background data in water for plutonium, uranium, americium, and tritium. The data are presented in Tables 17 and 18.

Drinking water from Boulder, Broomfield, and Westminster was collected weekly, composited monthly, and analyzed specifically for plutonium, uranium, and americium. Tritium analyses were performed on weekly grab samples. Quarterly grab samples of tap water were collected from the surrounding communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton. Samples were analyzed specifically for plutonium, uranium, americium, and tritium. Results also are presented in Tables 17 and 18.

Evaluation of the regional reservoir and drinking water data indicates no unusual results. The plutonium, uranium, americium, and tritium concentration data for the regional reservoirs represented a small fraction of the appropriate RCG_W (17 percent or less).[2,4] In the case of Great Western Reservoir, the average plutonium concentration was 4.1×10^{-4} Bq/ℓ (0.011×10^{-9} μCi/mℓ). This value is in the range of concentrations predicted for Great Western Reservoir in the Rocky Flats Plant Final Environmental Impact Statement.[1] The values given in the Impact Statement are based on known plutonium in the reservoir sediments. Results of the plutonium, uranium, americium and tritium data for 1981 drinking water in nine communities were all in the range of background. All values were 2.2 percent or less of the applicable RCG_W.[2,4]

Drinking water standards have been adopted by the EPA[8] and the State of Colorado[13] for alpha-emitting radionuclides (excluding uranium and radon) and for tritium. These standards are 5.55×10^{-1} Bq/ℓ and 740 Bq/ℓ (15×10^{-9} μCi/mℓ and $20{,}000 \times 10^{-9}$ μCi/mℓ), respectively. During 1981, the sum of the concentrations of plutonium and americium (alpha-emitting radionuclides) in each community tap water sample was 4×10^{-4} Bq/ℓ (0.01×10^{-9} μCi/mℓ) or less. That value is 0.07 percent or less of the alpha activity standard. The tritium concentrations in Great Western Reservoir, Standley Lake, and in all community tap water samples averaged less than 14.8 Bq/ℓ (400×10^{-9} μCi/mℓ). That value is typical of background tritium concentrations in Colorado and represents 2.0 percent or less of the EPA and State of Colorado Drinking Water Standard for tritium.[4,13]

TABLE 17. Plutonium, Uranium, and Americium Concentrations in Public Water Supplies

Reservoir	Number of Analyses	C_{min}	C_{max}	C_{avg}	Percent of RCG_w
		Plutonium Concentration ($\times 10^{-9}$ μCi/mℓ)[a]			
Boulder	1	0.001 ± 0.004	0.001 ± 0.004	0.001 ± 0.004	< 0.001
Dillon	1	-0.002 ± 0.004	-0.002 ± 0.004	-0.002 ± 0.004	< 0.001
Great Western	12	-0.001 ± 0.007	0.04 ± 0.03	0.011 ± 0.004	0.001
Ralston	1	-0.001 ± 0.004	-0.001 ± 0.004	-0.001 ± 0.004	< 0.001
South Boulder Diversion Canal	1	-0.001 ± 0.004	-0.001 ± 0.004	-0.001 ± 0.004	< 0.001
Standley	12	-0.005 ± 0.005	0.05 ± 0.02	0.002 ± 0.002	< 0.001
Drinking Water					
Arvada	4	-0.002 ± 0.002	0.05 ± 0.03	0.01 ± 0.01	0.001
Boulder	12	-0.004 ± 0.004	0.02 ± 0.01	0.004 ± 0.002	< 0.001
Broomfield	12	-0.004 ± 0.007	0.04 ± 0.02	0.005 ± 0.002	< 0.001
Denver	4	-0.001 ± 0.004	0.001 ± 0.004	0.000 ± 0.005	< 0.001
Golden	4	-0.02 ± 0.02	0.02 ± 0.08	0.00 ± 0.02	< 0.001
Lafayette	4	-0.002 ± 0.004	0.02 ± 0.01	0.004 ± 0.003	< 0.001
Louisville	4	-0.001 ± 0.004	0.02 ± 0.02	0.005 ± 0.005	< 0.001
Thornton	4	-0.003 ± 0.004	0.001 ± 0.004	-0.001 ± 0.005	< 0.001
Westminster	12	-0.006 ± 0.005	0.05 ± 0.02	0.006 ± 0.002	< 0.001
Reservoir		Uranium Concentration ($\times 10^{-9}$ μCi/mℓ)[b]			
Boulder	1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.25
Dillon	1	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	0.30
Great Western	12	-0.10 ± 0.07	5.1 ± 0.4	3.1 ± 0.1	1.6
Ralston	1	33 ± 1	33 ± 1	33 ± 1	17.
South Boulder Diversion Canal	1	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	0.30
Standley	12	2.0 ± 0.2	3.2 ± 0.2	2.6 ± 0.1	1.3
Drinking Water					
Arvada	4	-0.05 ± 0.05	3.6 ± 0.2	2.5 ± 0.1	1.3
Boulder	12	-0.19 ± 0.07	1.4 ± 0.2	0.22 ± 0.03	0.11
Broomfield	12	0.1 ± 0.1	3.8 ± 0.3	2.0 ± 0.1	1.0
Denver	4	1.2 ± 0.2	4 ± 1	2.1 ± 0.3	1.1
Golden	4	0.74 ± 0.08	2.6 ± 0.1	1.6 ± 0.1	0.8
Lafayette	4	-0.08 ± 0.09	0.69 ± 0.05	0.19 ± 0.04	0.10
Louisville	4	-0.15 ± 0.08	0.26 ± 0.04	0.05 ± 0.03	0.025
Thornton	4	0.7 ± 0.1	10.4 ± 0.3	4.4 ± 0.1	2.2
Westminster	12	1.4 ± 0.2	2.6 ± 0.2	1.69 ± 0.04	0.85
Reservoir		Americium Concentration ($\times 10^{-9}$ μCi/mℓ)[c]			
Boulder	1	-0.006 ± 0.007	-0.006 ± 0.007	-0.006 ± 0.007	< 0.001
Dillon	1	0.00 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	< 0.001
Great Western	12	-0.01 ± 0.01	0.01 ± 0.01	0.000 ± 0.003	< 0.001
Ralston	1	-0.004 ± 0.007	-0.004 ± 0.007	-0.004 ± 0.007	< 0.001
South Boulder Diversion Canal	1	-0.004 ± 0.007	-0.004 ± 0.007	-0.004 ± 0.007	< 0.001
Standley	12	-0.006 ± 0.009	0.01 ± 0.01	0.004 ± 0.004	< 0.001
Drinking Water					
Arvada	4	-0.008 ± 0.009	0.01 ± 0.01	0.000 ± 0.004	< 0.001
Boulder	12	-0.002 ± 0.009	0.01 ± 0.01	0.002 ± 0.002	< 0.001
Broomfield	12	-0.01 ± 0.01	0.02 ± 0.01	0.003 ± 0.002	< 0.001
Denver	4	0.00 ± 0.01	0.002 ± 0.007	0.001 ± 0.004	< 0.001
Golden	4	-0.01 ± 0.01	0.003 ± 0.007	-0.002 ± 0.004	< 0.001
Lafayette	4	-0.007 ± 0.006	0.003 ± 0.008	-0.001 ± 0.004	< 0.001
Louisville	4	-0.006 ± 0.009	0.01 ± 0.01	0.002 ± 0.004	< 0.001
Thornton	4	-0.006 ± 0.009	0.004 ± 0.005	-0.001 ± 0.008	< 0.001
Westminster	12	-0.01 ± 0.01	0.01 ± 0.01	-0.001 ± 0.002	< 0.001

a. Radiochemically determined as plutonium-239 and -240. The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is 1667×10^{-9} μCi/mℓ.

b. Radiochemically determined as uranium-233, -234, and -238. The most restrictive RCG_w for these uranium isotopes in the soluble form is 200×10^{-9} μCi/mℓ.

c. Radiochemically determined as americium-241. The RCG_w for soluble americium-241 is 1330×10^{-9} μCi/mℓ.

TABLE 18. Tritium Concentrations in Public Water Supplies

Reservoirs	Number of Analyses	Tritium Concentration ($\times 10^{-9}$ μCi/mℓ) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[a]
Boulder	1	800 ± 500	800 ± 500	800 ± 500	0.08
Dillon	1	600 ± 500	600 ± 500	600 ± 500	0.06
Great Western	51	-500 ± 600	800 ± 400	< 300	< 0.03
Ralston	1	500 ± 400	500 ± 400	500 ± 400	0.05
South Boulder Diversion Canal	1	600 ± 500	600 ± 500	600 ± 500	0.06
Standley	51	-300 ± 500	900 ± 500	< 300	< 0.03
Drinking Water					
Arvada	3	100 ± 400	600 ± 500	300 ± 300	0.03
Boulder	51	-700 ± 400	1100 ± 500	< 300	< 0.03
Broomfield	51	-400 ± 400	900 ± 500	< 300	< 0.03
Denver	3	100 ± 300	300 ± 500	200 ± 200	0.02
Golden	3	-100 ± 400	400 ± 500	100 ± 300	0.01
Lafayette	3	0 ± 500	700 ± 500	200 ± 300	0.02
Louisville	3	200 ± 400	500 ± 400	300 ± 300	0.03
Thornton	3	200 ± 400	500 ± 500	400 ± 300	0.04
Westminster	51	-400 ± 400	900 ± 500	< 300	< 0.03

a. The Radioactivity Concentration Guide (RCG_w) for tritium in water released to uncontrolled areas is 1,000,000 × 10^{-9} μCi/mℓ. The State of Colorado Primary Drinking Water Regulation limit for tritium is 20,000 pCi/ℓ or 20,000 × 10^{-9} μCi/mℓ.

G. Soil Sampling and Analysis

Soil samples were collected during 1981 as part of a long-range monitoring program. The program is designed to provide information on possible migration of plutonium in soil and to provide data for comparison with the EPA proposed guidance on transuranium elements in the environment.[5] The program was initiated in 1979 and will continue at least through 1983.

Samples were taken at three locations west of Indiana Street within the eastern boundaries of the Plant. The sites are shown on Figure 10 as numbers 16, 17, and 25. Sites 13 and 21 were sampled in 1979, sites 16 and 28 were sampled in 1980. The EPA comparison study has been performed at sites 13, 17, 21, 25, and 28 and will be continued at three additional sites in the future. The plutonium migration study is underway at site 16.

Nine composite samples, each composed of nine subsamples, were collected at site 17, which is immediately north of the East Access Road and west of Indiana Street. Collection was done according to published procedures.[5, 14] Each set of nine subsamples was collected on a spacing of 20 m (65.6 ft) and composited to yield one of the nine final samples. The geometry of each subsample was controlled by use of a 10 × 10 × 1 cm (4 × 4 × 0.4 in.), cutting tool. The soil contained within the tool cavity was removed and analyzed for plutonium. The same procedure was followed at site 25.

Plutonium concentrations in soil samples at sites 17 and 25 are shown in Table 19. As shown in the table, the values for the two locations range from 35 to 555 Bq/kg (0.95 to 15.0 pCi/g). The relative standard deviations of about 30 percent indicate that the plutonium deposition is uniformly distributed at both locations. The plutonium concentrations at site 17 ranged from 29.6 × 10^8 to 93.2 × 10^8 Bq/km² (80 to 252 mCi/km²). The median value at site 17 [40.0 × 10^8 Bq/km² (108 mCi/km²)] is 54 percent of the EPA proposed guideline for plutonium in soil.[5] The median concentration at site 25 was 12.6 × 10^8 Bq/km² (34 mCi/km²), which is 17 percent of the proposed guideline.

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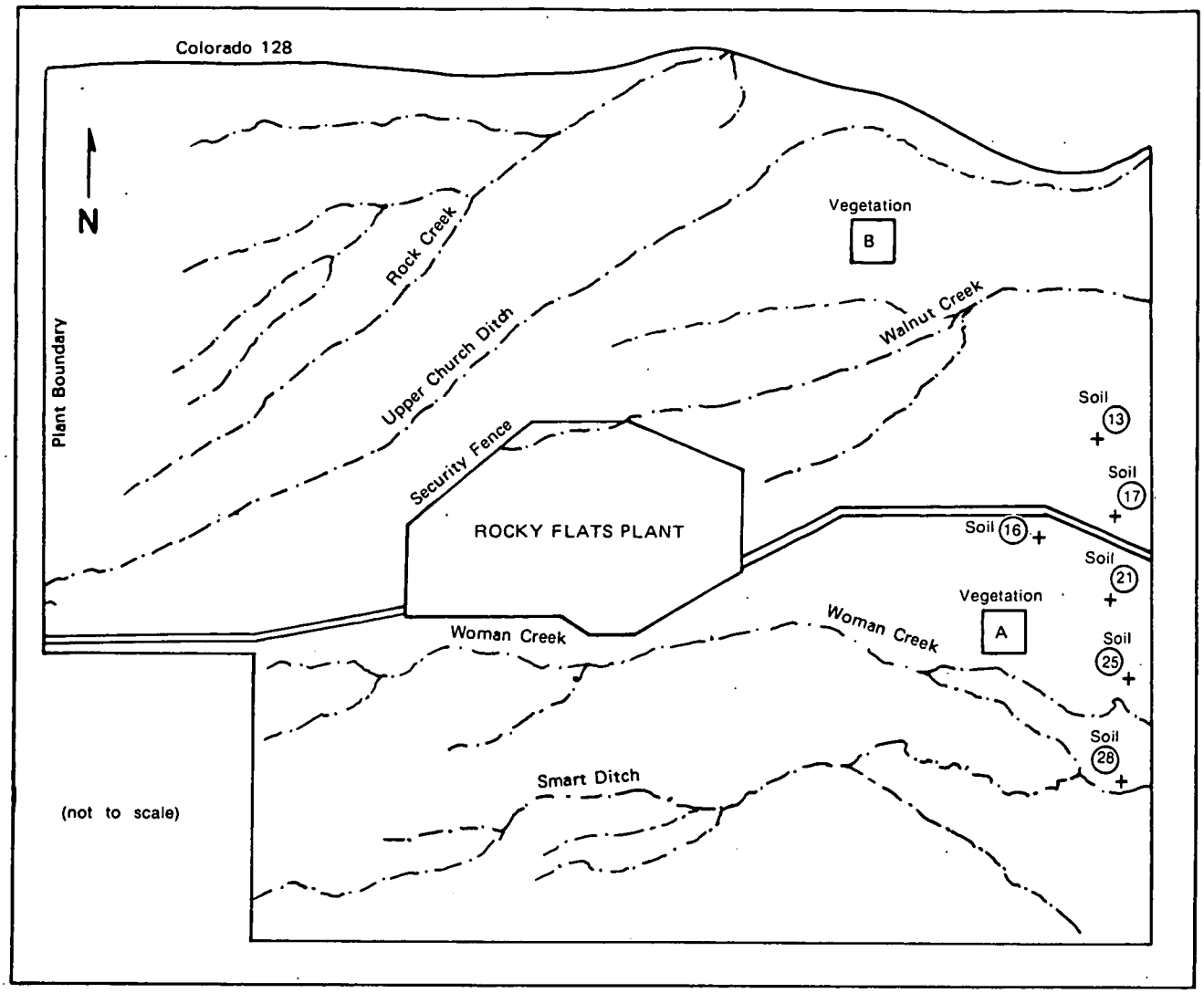

FIGURE 10. Location of Soil and Vegetation Sampling Plots

The second series of samples for the migration study was taken at site 16. (See Figure 10.) Thirty samples, made up of five composites each, were taken at 15 locations. These locations were selected on a random basis from a grid of 64 squares [2 m (6.6 ft) on each side of a square] separated by alleys 1-m wide. The subsamples were taken from the four corners and the center of each square. The remaining squares will be sampled in subsequent years to determine surface and depth changes in plutonium concentrations.

The samples from each square consisted of surface and core samples. Surface material was taken by means of a 10 X 10 X 5-cm (4 X 4 X 2 in.) cutting tool, and soil from the interior of the tool was carefully removed for analysis. The core samples were taken from the same sites as the surface samples by means of an orchard auger measuring 8.3 cm (3.3 in.) in diameter. The depth of the cores was from 5 to 20 cm (2 to 8 in.). Surface samples and core samples were retained as individual samples but received identical preparation and analysis.

Plutonium concentrations in surface soil and soil core samples at site 16 are shown in Table 20. The range of values for surface samples at site 16 was

TABLE 19. Plutonium Concentrations in Surface Soil Samples at the East Boundary of the Rocky Flats Plant

Location	pCi/g[a]	mCi/km²[b]	Location	pCi/g[a]	mCi/km²[b]
17-1	9.21 ± 0.97	112	25-1	1.44 ± 0.10	26
17-2	8.48 ± 0.70	112	25-2	2.46 ± 0.14	41
17-3	8.16 ± 0.73	103	25-3	2.38 ± 0.09	39
17-4	15.0 ± 0.78	252	25-4	2.59 ± 0.19	45
17-5	6.80 ± 0.43	103	25-5	1.46 ± 0.11	34
17-6	7.96 ± 0.72	112	25-6	1.63 ± 0.10	25
17-7	6.17 ± 0.59	108	25-7	1.74 ± 0.11	21
17-8	7.94 ± 0.77	91	25-8	0.95 ± 0.06	20
17-9	5.89 ± 0.52	80	25-9	1.76 ± 0.11	37
Mean	8.40 ± 0.72	119	Mean	1.82 ± 0.11	32
Median	7.96	108	Median	1.74	34
RSD[c]	32%	43%	RSD[c]	30%	29%

a. Concentrations are for the fraction of soil measuring less than 2 mm in size.
b. Samples were collected to a depth of 1 cm.
c. Percent relative standard deviation of the mean.

TABLE 20. Plutonium Concentrations in Soil Samples From Inside the Eastern Boundary of the Rocky Flats Plant

Location[c]	Surface[a] (pCi/g)[d]	Core[b] (pCi/g)[d]
16-4	13.0 ± 1.3	0.24 ± 0.03
16-7	9.24 ± 0.76	0.55 ± 0.06
16-11	22.8 ± 2.3	0.90 ± 0.04
16-22	10.8 ± 0.7	1.18 ± 0.10
16-26	15.3 ± 1.1	1.01 ± 0.08
16-27	8.96 ± 0.62	1.00 ± 0.08
16-29	9.33 ± 0.69	1.03 ± 0.10
16-31	12.8 ± 0.8	0.80 ± 0.05
16-35	8.35 ± 0.52	0.80 ± 0.06
16-36	7.89 ± 0.48	1.05 ± 0.07
16-42	8.54 ± 0.50	0.65 ± 0.04
16-45	7.84 ± 0.44	0.89 ± 0.07
16-52	7.10 ± 0.52	1.88 ± 0.14
16-58	7.10 ± 0.44	0.82 ± 0.07
16-62	8.72 ± 0.53	1.18 ± 0.09
Mean	10.52 ± 0.78	0.93 ± 0.07
Median	8.96	0.90
RSD[e]	39%	38%

a. Sampled to a depth of 5 cm (2 in.).
b. Sampled from 5 to 20 cm (2 to 8 in.).
c. The first number of each location refers to site 16 as shown in Figure 10. The second number is the sample location on the grid at site 16.
d. Concentrations are for the less-than-2-mm size fraction of soil.
e. Percent relative standard deviation of the mean.

between 263 and 844 Bq/kg (7.10 and 22.8 pCi/g) with a median of 332 Bq/kg (8.96 pCi/g). These values are within the range of those determined in 1980. Core samples contained plutonium in the range of 9.03 and 69.6 Bq/kg (0.24 and 1.88 pCi/g). The median value was 33.3 Bq/kg (0.90 pCi/g). These values are not significantly different from those measured in 1980.

H. Vegetation Sampling and Analysis

Vegetation from the Rocky Flats Plant is periodically sampled and analyzed for plutonium-239 and -240, plutonium-238, and americium-241. This sampling is part of a long-term ecological monitoring program designed to aid in evaluating the environmental impact of the Plant. A comparison of these data with data from vegetation samples collected in succeeding years will provide information regarding long-term trends.

During July 1981, all standing vegetation was clipped from 1.0-m^2 frames located randomly at 10 sites in each of two plots (Figure 10). Vegetation samples were also collected from Lafayette, Colorado, which is approximately 16 km (10 mi) northeast of the Plant, and were employed as controls. All vegetation samples were oven dried at 95-100 °C and were submitted to the Health, Safety and Environmental Laboratories for ashing and radionuclide analyses. A statistical summary of the data is presented in Table 21.

Application of one-sided t-tests to the plutonium-239, -240 data indicated that Plot A vegetation samples contained significantly more of these radionuclides than control samples. There was no statistically significant difference between vegetation from Plot B versus control or Plot B versus Plot A. Because 26 of the 45 plutonium-238 and americium-241 values were less than zero, no statistical comparisons of these data are presented here.

J. External Gamma Radiation Dose Monitoring

Thermoluminescent dosimeters (TLD's) are used to measure external penetrating gamma radiation exposure at 45 locations on and off the Plant site. Two TLD's are placed at each location for an exposure period of three months. The TLD's are placed at 17 locations within the property enclosed by the security fence shown in Figure 2. Measurements are also made at 16 perimeter locations 3 to 6 km (2 to 4 mi) from the Plant and in 12 communities located within 50 km (30 mi) of the Plant. The TLD's are placed at a height of 1 m (3 ft) above ground level.

Each TLD consists of a sealed glass bulb enclosing two extruded ribbons of CaF_2:Mn (TLD-400) that sandwich a central metal heater strip. The TLD's are encased in an energy-compensating shield to reduce over-response to photons with energies less than about 100 keV. The use of TLD's for assessing external penetrating radiation in the environment has been evaluated under field and laboratory conditions and has been found to be a sensitive and reliable tool for environmental measurement of gamma radiation exposure.[15]

The environmental dosimeters have been individually calibrated (five times each) against an onsite gamma calibration source. The average calibration factor for each dosimeter is applied to measurements taken with that dosimeter. An additional correction is applied to correct for day-to-day variations in reader calibration.

Environmental measurements made in 1981 using TLD's are summarized in Table 22. The average annual dose equivalents, as measured onsite, in the perimeter environs, and in communities, were 1.34, 1.25, and 1.41 mSv (134, 125, and 141 mrem), respectively. These values are indicative of background gamma radiation in the area.[9]

K. Aerial Radiological Survey

During August 12 through August 18, 1981, an aerial radiological survey of the Rocky Flats Plant and some adjacent offsite land was conducted by EG&G, Inc. of Las Vegas, Nevada. The survey was done for the Department of Energy and was funded by the Nevada Operations Office. The survey consisted of measurements, using a Boeing BO-105 helicopter, of natural and man-made gamma radiation from the terrain surface in and around the Rocky Flats Plant. This aerial measuring opera-

TABLE 21. Plutonium and Americium Concentrations in Vegetation From Plots A and B
(Values are picocuries per gram of ash, blank corrected)

	Pu-239, -240			Pu-238			Am-241		
	Number of Analyses	$\bar{X}$	SD	Number of Analyses	$\bar{X}$	SD	Number of Analyses	$\bar{X}$	SD
Plot A	10	0.08	0.05	10	-0.02	0.01	9	0.06	0.02
Plot B	10	0.06	0.08	10	-0.01	0.02	10	-0.01	0.04
Control	3	0.009	0.003	3	-0.002	0.002	3	-0.044	0.009

TABLE 22. Environmental Thermoluminescent Dosimeter Measurements

Location Category	Number of Locations	Number of Measurements	Annual Measured Dose (mrem)*
Onsite	17	125	134 ± 3
Perimeter	16	126	125 ± 3
Community	12	93	141 ± 4

*The error terms reported represent the 95 percent confidence interval for the standard error of the mean (1.96 $\sigma_{\bar{x}}$), calculated from the variance of the individual measured values.

tion was considered a routine part of the radiological surveys that are conducted from time to time on certain government-owned plants dealing with radioactive materials.

The survey covered an area of approximately 93 km^2 (36 mi^2) and was conducted from the helicopter, which flew at 46-m (150 ft) altitude along lines of 76-m (250 ft) spacing. The measurement system included two pods, each containing 10 sodium iodide detectors. The data collection, processing, and analysis systems were computerized and contained a 1024 channel analyzer with data finally compressed into 256 channels and recorded every second.

The integral counting rate in the 0.5 to 3.0 MeV portion of the energy spectrum was converted to exposure rate in μR/hr at 1 m above ground level. The terrestrial gamma ray exposure rate isopleth is reproduced on a photograph of the surveyed area (Figure 11). This isopleth includes a cosmic ray exposure rate of 5.6 μR/hr and is the total exposure rate from natural soil radionuclides, cosmic rays, and man-made sources.

Figure 11 is a simplified version of the original, in which isopleth categories A, B, C, and D were drawn separately and were far too numerous for presentation at this reduced scale. All areas that correspond to categories E and F are reproduced here.

V. ASSESSMENT OF POTENTIAL PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

Potential public radiation dose commitments, which could have resulted from Plant operations, were calculated from average radionuclide concentrations measured at the DOE property boundaries and in surrounding communities. Inhalation, water ingestion, and ground-plane irradiation were found to be the principal pathways of exposure. Swimming and consumption of foodstuffs and fish were found to be insignificant pathways. This latter finding is to be expected because of limited swimming and fishing in the area and because most locally consumed food is produced at considerable distances from the Plant.

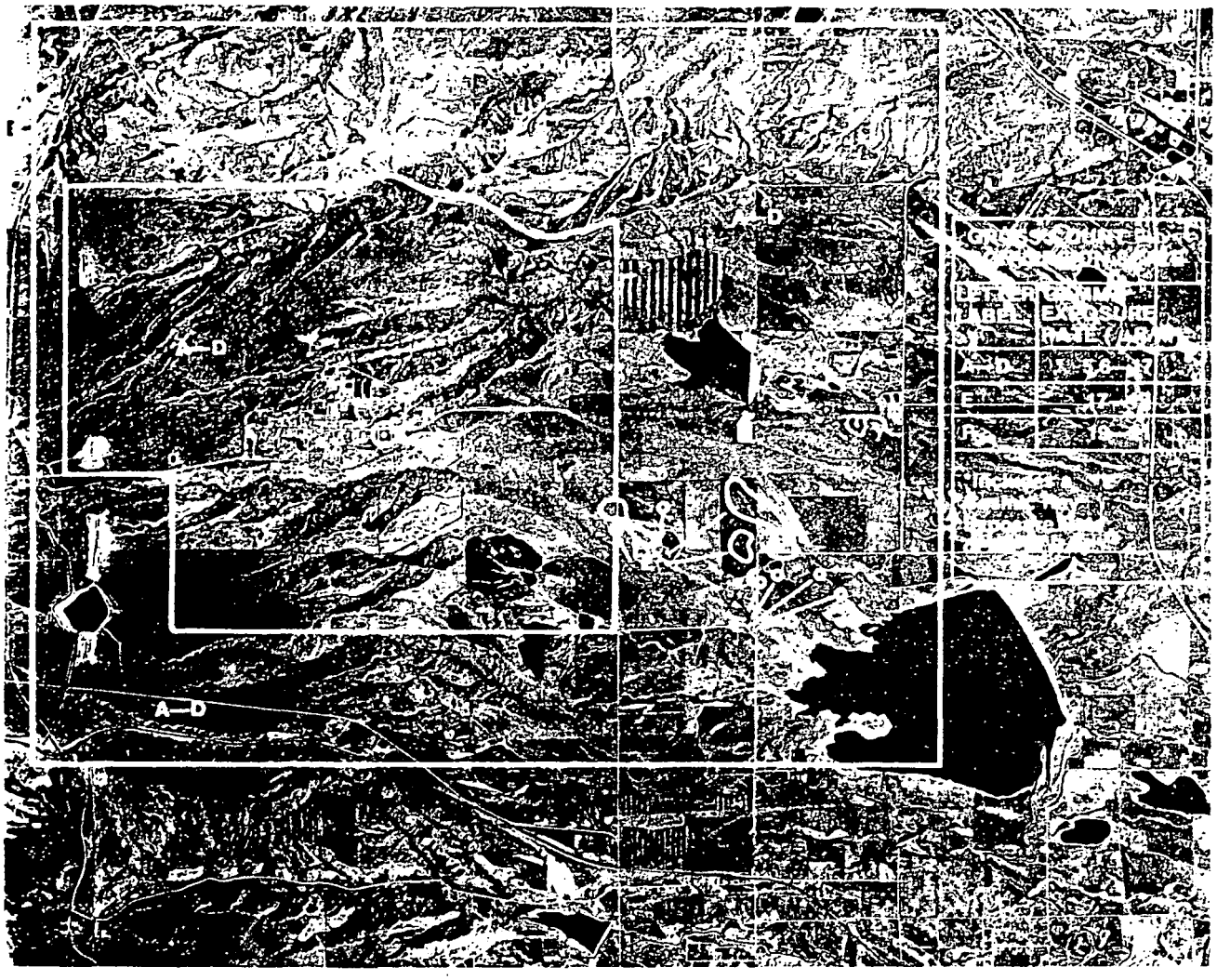

FIGURE 11. Aerial Radiological Survey Area

Dose assessment for 1981 Plant operations was conducted for several locations: the DOE property (site) boundary, nearby communities, and sites to a distance of 80 km (50 mi). Dose conversion factors used for the calculations were generated by computer codes that are described in detailed reports.[16,17] These conversion factors are listed in Table 23. The inhalation rate of 2.66×10^{-4} m^3/s and the water ingestion rate of 1.65 ℓ (1.75 qt) per day were derived from data for reference man,[18] and were included in the dose conversion factors. Each of these dose conversion factors is for a 70-year dose commitment from one year of chronic exposure.

In deriving the inhalation source terms, solubility class W is used for radionuclides in the total body, liver and bone. Solubility class W is defined by the ICRP Task Group on Lung Dynamics as material with a maximal clearance half-time from the lungs ranging from a few days to a few months. Solubility class Y, which is used by the ICRP to describe materials retained in the lungs, with a maximal biological half-time ranging from 6 months to several years, is used for the lungs. Obviously the inhaled material cannot be both Class W and Class Y simultaneously as this treatment suggests; however since the exact solubility of the inhaled material is

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TABLE 23. Dose Conversion Factors Used in Dose Assessment Calculations[a]

	Inhalation[b] (rem·cubic meter / Curie)	Water Ingestion[c] (rem·liter / Curie)			Ground Plane Irradiation (rem·square meter / Curie)	
Organ	Pu-239, -240	Pu-239, -240	Am-241	U-233, -234	Pu-239, -240	Am-241
Total Body	8.60×10^{10}	5.22×10^{6}	5.33×10^{7}	4.41×10^{4}	2.84×10^{2}	7.57×10^{3}
Liver	9.99×10^{12}	6.03×10^{8}	6.21×10^{9}	(d)	(d)	(d)
Bone	2.50×10^{13}	1.51×10^{9}	1.49×10^{10}	(d)	(d)	(d)
Lung	6.31×10^{12}	(d)	(d)	(d)	(d)	(d)

a. These factors are taken from the Rocky Flats Plant Environmental Impact Statement.[1]
b. For 0.3-μm AMAD (Activity Median Aerodynamic Diameter), inhalation rate of 2.66×10^{-4} m^3/s for chronic exposure [18]
c. For intake rate of 1.65 ℓ (1.75 qt) per day.[18]
d. Values for the conversion factor are taken to be equal to that for the total body.

not known, this treatment is conservatively used to yield a maximum calculated dose to any of the referenced organs regardless of the actual solubility.

A. Dose Assessment Source Terms

Plutonium and americium in the Rocky Flats environs are the combined result of fallout deposition from atmospheric nuclear weapons testing and of past releases from the Plant. Uranium, a naturally occurring element, is indigenous to many parts of Colorado and also is used in Plant operations in various isotopic ratios. Tritium, a radionuclide formed by natural processes, also is associated with Plant operations and fallout.

Inhalation source terms for the 1981 dose assessment were based on plutonium-239 and -240 concentrations measured in ambient air samples. Because of the presence of plutonium from atmospheric weapons testing in previous years, those concentrations are an overestimate of the Rocky Flats contribution. The ingestion source terms were based on measured concentrations of plutonium, americium, uranium, and tritium in water. The ground plane source terms were based on measured values of plutonium in soil and an assumed ratio of americium to plutonium alpha activity (0.20) in the soil. This ratio is the maximum level of americium in-growth from Rocky Flats plutonium.[1]

The maximum site-boundary dose assessment assumes that an individual is continuously present at the Plant perimeter, which actually is uninhabited. The plutonium inhalation source term of less than 8.5×10^{-7} Bq/m^3 (2.3×10^{-17} Ci/m^3) was the maximum concentration of plutonium-239, and -240, as measured for a single perimeter location in the perimeter ambient air sampling network.

The water supply for the individual at the site boundary was assumed to be Walnut Creek, which flows offsite and provides the liquid effluent source term at the site boundary. During 1981, the plutonium concentration in Walnut Creek averaged 7×10^{-4} Bq/ℓ (2×10^{-14} Ci/ℓ). The average americium concentration was less than 4×10^{-4} Bq/ℓ (1×10^{-14} Ci/ℓ). These concentrations were used as the water ingestion source term for the maximum site boundary dose assessment. The average concentration of uranium in Walnut Creek was 2.8×10^{-1} Bq/ℓ (7.6×10^{-12} Ci/ℓ) while the uranium in raw water, flowing into the Plant, was 1.1×10^{-1} Bq/ℓ (2.9×10^{-12} Ci/ℓ). The source term for uranium ingestion was the difference of these two values [1.7×10^{-1} Bq/ℓ (4.7×10^{-12} Ci/ℓ)]. The average tritium concentration in Walnut Creek was 1.5×10^{1} Bq/ℓ (4.0×10^{-10} Ci/ℓ), which is within the range typically measured in regional waters. Tritium in the water was, therefore, omitted from the dose assessment.

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TABLE 24. Radioactivity Concentrations Used for 1981 Dose Calculations

	Air (Ci/m³)	Water (Ci/ℓ)			Surface Deposition (Ci/m²)	
Location	Pu-239, -240	Pu-239, -240	Am-241	U-233, -234	Pu-239, -240	Am-241
Maximum Site Boundary	2.3×10^{-17}	2×10^{-14}	1×10^{-14}	4.7×10^{-12}	3×10^{-8}	6×10^{-9}
Community	3.0×10^{-17}	–	–	–	–	–

The ground-plane irradiation source term is based on the maximum plutonium-in-soil deposition at the Plant perimeter, as reported by the Environmental Measurements Laboratory.[19] This source term is 1×10^{3} Bq/m² (3×10^{-8} Ci/m²). The americium is assumed to be present at an alpha activity level of 20 percent that of the plutonium, which is the maximum quantity of americium that can be present in Rocky Flats plutonium from the decay of plutonium-241.[1] The americium source term therefore is 2×10^{2} Bq/m² (6×10^{-9} Ci/m²).

The source terms and corresponding dose commitments were evaluated for each of the surrounding communities, to determine the maximum community exposure. The ground-plane irradiation and water ingestion pathways were insignificant for all of the communities; i.e., these pathways contribute less than 10 percent of the total dose. The only significant pathway for radiation exposure was inhalation of plutonium in air. The source term for inhalation used in the dose assessment was the maximum annual average plutonium concentration measured in community ambient air [1.1×10^{-6} Bq/m³ (3.0×10^{-17} Ci/m³)]. This concentration was the annual average concentration measured in the Boulder ambient air sampler. The difference between the measured concentration in Boulder and the other communities is not, however, considered to be statistically significant.

A summary of the source terms for the maximum site boundary and for community locations is tabulated in Table 24.

B. Maximum Site Boundary Dose

The maximum dose to an individual continuously present at the site boundary is based on the radionuclide concentrations shown in Table 24. From these concentrations and the dose conversion factors in Table 23, a 70-year dose commitment of 6×10^{-7} Sv (6×10^{-5} rem) is calculated for the total body. The corresponding bone dose is 9×10^{-6} Sv (9×10^{-4} rem). The DOE radiation protection standards for individuals in uncontrolled areas are 5×10^{-3} Sv (5×10^{-1} rem) annually for the total body and 1.5×10^{-2} Sv (1.5 rem) each year for mineral bone.[2] The maximum site boundary dose represents less than 0.02 percent of the standard for total body and less than 0.06 percent of the standard for mineral bone.

C. Maximum Community Dose

Based on radionuclide concentrations in surrounding communities (Table 24), the calculated 70-year dose commitments were 3×10^{-8} Sv (3×10^{-6} rem) to the total body and 8×10^{-6} Sv (8×10^{-4} rem) to the bone. These values represent less than 0.002 percent and 0.2 percent, respectively, of the 1.7×10^{-3} Sv (1.7×10^{-1} rem) annual total body standard for a suitable sample of the exposed population and 5×10^{-3} Sv (5×10^{-1} rem) standard for mineral bone.[2]

The maximum site boundary and community dose commitments are summarized in Table 25. These values may be compared to an average dose reported for the Denver area of 1.5×10^{-3} and 1.68×10^{-3} Sv/yr (1.5×10^{-1} and 1.68×10^{-1} rem/yr) to the total body and bone, respectively, from natural radiation. (See Table 26.)

TABLE 25. Seventy-Year Dose Commitment From One Year of Chronic Intake/Exposure

Source	Total Body (rem)	Liver (rem)	Bone (rem)	Lungs (rem)
Maximum Site Boundary Location	6×10^{-5}	4×10^{-4}	9×10^{-4}	2×10^{-4}
Community	3×10^{-6}	3×10^{-4}	8×10^{-4}	2×10^{-4}

TABLE 26. Natural Radiation Background Dose for the Denver Metropolitan Area[a]

Source	Total Body[b] (rem/yr)	Liver[b] (rem/yr)	Bone (rem/yr)	Lungs (rem/yr)
Cosmic Radiation	0.050	0.050	0.050	0.050
Cosmic Radionuclides	0.0007	0.0007	0.0008	0.0007
External Terrestrial	0.072	0.072	0.057	0.072
Inhaled Radionuclides	–	–	–	0.100
Radionuclides in the Body	0.027	0.027	0.060	0.024
Total for One Year	0.1497	0.1497	0.1678	0.2467

a. Values in this table are a summary of values derived from Reference 18.
b. Values for the total body and liver are considered to be the same as the values reported for gonads in Reference 18.

D. Eighty-Kilometer Dose Estimates

The dose commitment for all individuals to a distance of 80 km (50 mi) is based on the calculated maximum community dose estimates shown in Table 25. Estimated dose commitments for each of the specific organs are all less than 1×10^{-5} Sv (1×10^{-3} rem or 1 mrem). A level of "~1 mrem/yr" or less is specified as a de minimis (inconsequential) level of exposure in the DOE prescribed standard A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA).[20] The Guide further states:

> "Radiation-induced mutations and diseases have not been discovered in populations that are or have been exposed to doses of 100 mrem/yr or less. Hence, it is reasonable to suggest that no health effects will be discerned if a population is exposed to an additional 1% of the level; i.e., ~1 mrem/yr. An annual dose of 1 mrem should be regarded as a level which is clearly de minimis."

Based on the de minimis concept in the Guide and on the maximum community dose estimates, the dose commitment for all individuals to 80 km is considered to be de minimis.

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VI. APPENDIXES

APPENDIX A
APPLICABLE GUIDES AND STANDARDS

The Rocky Flats Plant Environmental Monitoring Program includes evaluating Plant compliance with all relevant guides, limits, and standards. Guide values for radionuclides in ambient air and waterborne effluents have been adopted by the Department of Energy (DOE) and the Colorado Department of Health (CDH).[2, 4] The guides are based on recommendations published by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP). Limits for nonradioactive pollutants in effluent water have been defined by an Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES) discharge permit.[7] In 1976, the EPA also established standards for radionuclides in drinking water.[8] These drinking water standards have been adopted, in turn, by the State of Colorado.[13]

The Radioactivity Concentration Guides (RCG's) published by DOE and CDH include permissible concentrations of specific radionuclides and mixtures of radionuclides in air (RCG_a) and water (RCG_w) for individuals in controlled and uncontrolled areas.[2, 4] Those guides are reduced by a factor of three when applied to a suitable sample of the exposed population. Numerical values of the guides for specific radionuclides are cited in some of the tables presented in this report. The guides additionally restrict the concentration of radionuclides in a mixture such that the sum of the ratios of each radionuclide concentration to the appropriate concentration guide shall not exceed a value of 1. The guides further state that a radionuclide may be considered as not being present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture to the concentration guide for that radionuclide does not exceed one-tenth and (b) the sum of such ratios for all radionuclides considered as not being present in the mixture does not exceed one-fourth. During 1981, average specific radionuclide concentrations in ambient air and water met both criteria (a) and (b), except for uranium in Ralston Reservoir. Since Rocky Flats effluent waters are not tributary to Ralston Reservoir, the measured concentrations in this report have all been compared to the concentration guides for specific radionuclides rather than for the entire mixture.

The RCG's for each radionuclide are specified for soluble and insoluble material. For purposes of comparing concentrations to RCG's, the more restrictive of the two (soluble or insoluble) RCG's is used. In this report, the RCG's for americium, plutonium, uranium, and tritium are referenced. The more restrictive RCG's for americium, plutonium, uranium, and tritium are for soluble material. Throughout this report, where a radionuclide concentration is expressed as the cumulative measurement of more than one isotope, the stated RCG used for comparison represents the most restrictive RCG for that grouping of isotopes. Plutonium concentrations measured at Rocky Flats represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the Plant.

Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Fully enriched and depleted uranium are the principal types of uranium handled at Rocky Flats. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium; however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The uranium RCG's used in this report for air and water are those for uranium-233, -234.

and uranium-238, respectively, which are the most restrictive.

Environmental uranium concentrations can be measured by a variety of laboratory techniques. Nonradiological techniques yield concentration units of mass per unit volume such as micrograms per cubic meter ($\mu g/m^3$) and micrograms per liter ($\mu g/\ell$). The uranium concentrations given in this report were derived by measuring radioactivity from alpha-emitting uranium isotopes and are expressed in terms of activity units per unit volume. Rocky Flats data include measurements of depleted uranium, fully enriched uranium, and natural uranium.

Conversion factors for specific types of uranium can be used to compare the data in this report to data from other facilities and agencies that are given in units of mass per unit volume; however, the resulting approximations will not have the same assurance of accuracy as that for the original measured values. Uranium in effluent air from Plant buildings is primarily depleted uranium. The conversion factor for this data is 2.6×10^6 g/Ci. Natural uranium is the predominant form found in water. The conversion factor for water data is 1.5×10^6 g/Ci.

The applicable EPA standard for beryllium (a nonradioactive material) in airborne effluents from Plant buildings is 10 g per stationary source in a 24-hr period.[11] For ambient air, the applicable DOE and CDH RCG's for soluble plutonium-239 and -240 in uncontrolled areas and for the general population are 2.2×10^{-3} Bq/m^3 (60×10^{-15} μ Ci/mℓ) and 7.4×10^{-4} Bq/m^3 (20×10^{-15} μCi/mℓ), respectively.[2,4]

The DOE and CDH soluble plutonium-239 and -240 RCG in waterborne effluents for the general population is 62 Bq/ℓ ($1{,}667 \times 10^{-9}$ μCi/mℓ).[2,4] The comparable RCG for americium-241 in water is 49 Bq/ℓ ($1{,}330 \times 10^{-9}$ μCi/mℓ).[2,4]

The most restrictive RCG for uranium-233, -234, and -238 in water is 7.4 Bq/ℓ (200×10^{-9} μCi/mℓ), which is the RCG for soluble uranium-238.[2]

In 1976, the EPA promulgated regulations for radionuclides in drinking water.[8] These regulations were effective on June 24, 1977 along with primary drinking water regulations for microbiological, chemical, and physical contaminants. The intent of the Safe Drinking Water Act was to ensure that each state has primary responsibility for maintaining drinking water quality. To comply with these requirements, the Colorado State Board of Health modified existing State drinking water standards to include radionuclides.[13] Two of the community drinking water standards are of interest in this report. The State standard for gross-alpha particle activity (including radium-226 but excluding radon and uranium) in community water systems is a maximum of 5.6×10^{-1} Bq/ℓ (15 pCi/ℓ or 15×10^{-9} μCi/mℓ). Americium and plutonium, which are alpha-emitting radionuclides, are included in this limit. The limit for tritium in drinking water is 740 Bq/ℓ (20,000 pCi/ℓ or $20{,}000 \times 10^{-9}$ μCi/mℓ).

The Rocky Flats Plant NPDES permit, which the EPA issued in 1981 to DOE, established (1) sanitary effluent limitations on discharge from Pond B-3 (sewage effluent), (2) limitations for nitrate and pH in the discharge from Holding Pond A-3 in the Walnut Creek drainage, (3) limitations on discharge from the reverse osmosis pilot plant on Woman Creek, (4) limitations on discharge from the reverse osmosis plant, and (5) control of sediment release during discharges from Ponds A-4, B-5, and C-2.

In addition to evaluating compliance with all relevant guides, limits, and standards, the Environmental Sciences Branch assists operating groups in adhering to the DOE policy that ". . . operations shall be conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable."[2]

Table A-1 shows applicable standards for radioactive and nonradioactive materials.

TABLE A-1. Applicable Standards for Radioactive and Nonradioactive Materials

Legend

μCi = microcuries
m^3 = cubic meters
mℓ = milliliters
mg/ℓ = milligrams per liter
SU = standard units
NA = not applicable
g = grams
40 CFR 61 = Code of Federal Regulations National Emission Standards for Hazardous Air Pollutants (USEPA)
DOE = Department of Energy
NPDES = National Pollutant Discharge Elimination System
CDH = Colorado Department of Health

Parameter	Applicable Guides and Standards	Reference
Airborne Effluents		
Plutonium-239, -240	NA	Not applicable
Uranium-233, -234, -238	NA	Not applicable
Tritium	NA	Not applicable
Beryllium	< 10.0 g/day	40 CFR 61.32(a)
Ambient Air		
Plutonium-239, -240	$< 20.0 \times 10^{-15}$ μCi/mℓ	DOE Order 5480.1, CDH
Waterborne Effluents Radioactive		
Plutonium-239, -240	$< 1{,}667 \times 10^{-9}$ μCi/mℓ	DOE Order 5480.1, CDH
Uranium-233, -234, -238	$< 200 \times 10^{-9}$ μCi/mℓ	DOE Order 5480.1
Americium-241	$< 1{,}330 \times 10^{-9}$ μCi/mℓ	DOE Order 5480.1, CDH
Tritium	$< 1{,}000 \times 10^{-6}$ μCi/mℓ	DOE Order 5480.1, CDH

Discharge Limitations*

Parameter	Monthly Average	Daily Maximum	Reference
Effluent Water Samples (Nonradioactive)			
pH	6.0–9.0 SU		NPDES Permit
Nitrate as N	10 mg/ℓ	20 mg/ℓ	NPDES Permit
Total Phosphorus	8 mg/ℓ	NA	NPDES Permit
Biochemical Oxygen Demand, 5-Day	10 mg/ℓ	25 mg/ℓ	NPDES Permit
Suspended Solids	30 mg/ℓ	45 mg/ℓ	NPDES Permit
Total Chromium	0.05 mg/ℓ	0.1 mg/ℓ	NPDES Permit
Residual Chlorine	NA	0.5 mg/ℓ	NPDES Permit
Oil and Grease	NA	Visual	NPDES Permit
Fecal Coliform Count	400 organisms/100 mℓ (7 day)		NPDES Permit
Fecal Coliform Count	200 organisms/100 mℓ (30 day)		NPDES Permit
Total Organic Carbon	22 mg/ℓ	30 mg/ℓ	NPDES Permit

*These limitations are presented as indicators of the types of parameters and associated concentration limits required by the NPDES Permit. Details of these requirements specific to each discharge location are given in the referenced document.[7] The daily and monthly limitations indicated cannot be correlated with the annual water quality data summarized in Table 11.

APPENDIX B
QUALITY CONTROL

A Quality Program Plan has been developed by the Environmental Analysis (EA) Section to provide controls for assurance that

- Current operating procedures exist for all phases of EA operations and that these procedures are implemented as written.
- Appropriate approvals are obtained prior to program initiation or change.
- The equipment used in sample collection and data analysis is appropriate to the assigned function and is operating as required.
- Accurate documentation exists for all programs, procedures, and actions.
- All variances from procedures or equipment use and performance are documented and explained with an impact assessment.
- Appropriate guidelines and standards for environmental monitoring are identified, and documentation of compliance is provided on a routine basis to Rocky Flats management, DOE, and to State and Federal regulatory agencies.

The Quality Program Plan establishes control points and delineates responsibilities for specific categories of activities; provides an information base from which procedures can be developed, updated, and/or implemented; establishes a state of emergency preparedness in its contingency plans; and provides documented evidence of Rockwell's intent to comply with rules and regulations of Federal, State, and local regulatory agencies.

The plan includes quality assurance flow charts and quality matrices that illustrate activity networks and corresponding quality elements of each responsibility area. A complete listing of activities and responsibilities is also included in the Plan.

To ensure data reliability, the Health, Safety and Environmental Laboratories (HS&EL) Quality Control Program Plan outlines the quality control methods used in all phases of laboratory operations.

This quality control program includes the following elements:

- Development, evaluation, improvement, modification, and documentation of analytical procedures
- Scheduled instrument calibration, control charting, and preventive maintenance
- Participation in interlaboratory quality comparison programs
- Intralaboratory quality control programs

All sample batches scheduled for analysis by the HS&EL Central Receiving Laboratory contain an average of 10 percent control samples. The controls consist of analytical blanks prepared in-house and standards prepared by the Rocky Flats Chemistry Standards Laboratory.

An analysis or group of analyses may be rejected and the sample or samples scheduled for re-analysis for one or more of the following reasons:

1. The chemical recovery is less than 10 percent or greater than 110 percent.
2. The analytical blanks in the analysis batch are out of acceptable range.
3. The standards in the analysis batch are not within acceptable limits of error.
4. The alpha energy spectrum is not acceptable because of the following:

   a. extra and/or unidentified peaks

b. excess noise in background areas

c. poor resolution of peaks

5. The chemist in charge of the laboratory believes there is reason to suspect the analysis.

Any unusual condition affecting the results, which is noted either during sample collection or analysis, is reported to Environmental Analysis.

Table B-1 is a summary of HS&EL participation in the Rocky Flats Chemistry Standards Laboratories Bioassay and Environmental Measurements Program for 1981.

The HS&EL participate in two laboratory intercomparison programs:

1. The DOE Environmental Measurements Laboratory (EML) Crosscheck Program
2. The EPA Environmental Monitoring Systems Laboratory (EMSL) Crosscheck Program

Tables B-2 and B-3 summarize the HS&EL participation in both programs.

TABLE B-1. Health, Safety and Environmental Laboratories Bioassay and Environmental Measurements Program Data

(January Through December 1981)

Isotopes Reported	Matrix	Method	Standard Range	Normal Sample Range	Annual Relative Percent Error[a]	Total Control Analyses
Pu-239, -240	Water	Alpha Spectral	0-20 d/m/ℓ	0-2 d/m/ℓ	-1	60
Am-241	Water	Alpha Spectral	0-3 d/m/ℓ	0-1 d/m/ℓ	+4	60
U-238, -234, -235	Water	Alpha Spectral	0-35 d/m/ℓ	0-20 d/m/ℓ	-6	60
Pu-239, -240	Whatman Filters	Alpha Spectral	0-30 d/m/filter	0-10 d/m/filter	-8	120
Am-241	Whatman Filters	Alpha Spectral	0-4 d/m/filter	0-2 d/m/filter	+8	120
U-238, -234, -235	Whatman Filters	Alpha Spectral	0-30 d/m/filter	0-30 d/m/filter	-4	120
Be[b]	Whatman Filters	Atomic Absorption	1-5 μg/filter	0-2 μg/filter	-25	120
Pu-239, -240	Microsorban Filters	Alpha Spectral	0-50 d/m/filter	0-20 d/m/filter	-10	48
^{3}H	Water	Beta Liquid	0-5 x 10^{4} pCi/ℓ	0-10^{4} pCi/ℓ	-5	60

a. The ratio of the deviations of the 12-month differences to standard value in percent; i.e., observed value minus standard value divided by standard value times 100 equal the ratio as expressed in percent. The relative error for control measurements is often called the coefficient of variation where the dispersion of data (in this case, the average differences between measured and standard values) is divided by the average standard value submitted. This term is inclusive of all random and systematic error in the standards, analytical chemistry, and measurement process for a given nuclide, matrix, and procedure.

b. Analyzed by 881 General Laboratory.

TABLE B-2. Health, Safety and Environmental Laboratories Participation in the Environmental Measurements Laboratory Interlaboratory Comparison Program[a]

Matrix	Isotope	Method	HS&EL Value	HS&EL Percent Error	EML Value	Units	Ratio[b] RFP/EML
Soil	Pu-239	Alpha Spectral Analysis	0.920E00	16	0.720E00	pCi/g	1.28 ± 0.37
Soil	U-234	Alpha Spectral Analysis	0.620E00	19	0.780E00	pCi/g	0.79 ± 0.16
Soil	U-238	Alpha Spectral Analysis	0.740E00	19	0.860E00	pCi/g	0.86 ± 0.16
Vegetation	U-234	Alpha Spectral Analysis	0.170E00	29	0.110E00	pCi/g	1.55 ± 0.62
Vegetation	U-238	Alpha Spectral Analysis	0.150E00	53	0.110E00	pCi/g	1.36 ± 0.77
Water	^{3}H	Beta Liquid Scintillation	0.256E02	3	0.246E02	pCi/mℓ	1.04 ± 0.05
Water	Pu-239	Alpha Spectral Analysis	0.589E-02	14	0.550E-02	pCi/mℓ	1.07 ± 0.15
Water	Am-241	Alpha Spectral Analysis	0.390E-02	13	0.420E-02	pCi/mℓ	0.92 ± 0.12
Water	U-234	Alpha Spectral Analysis	0.545E-02	15	0.510E-02	pCi/mℓ	1.07 ± 0.16
Water	U-238	Alpha Spectral Analysis	0.518E-02	17	0.510E-02	pCi/mℓ	1.02 ± 0.19

a. This program was cancelled as of 10/2/81 submission.

b. = $\frac{\text{Rocky Flats Plant Reported Value}}{\text{EML Known Value}}$

TABLE B-3. Health, Safety and Environmental Laboratories Participation in the EPA Environmental Monitoring Systems Laboratory Crosscheck Program

Isotope Reported	Matrix	Method	Number of Analyses Reported	Relative Percent Error
^{3}H	Water	Beta Liquid Scintillation	4	4
Pu-239	Water	Alpha Spectral Analysis	2	-8
Total U	Water	Alpha Spectral Analysis	1	3

APPENDIX C
ANALYTICAL PROCEDURES

The Health, Safety and Environmental Laboratories (HS&EL) routinely perform the following analyses on environmental effluent samples:

1. Gross Alpha
2. Gross Beta
3. Gamma Spectral Analysis
4. Alpha Spectral Analysis (Pu-239, -238 Am-241, U-238, -233, -234)
5. Beta Liquid Scintillation - Tritium
6. Iodometric Titration - Chlorine
7. Bacteria
8. Atomic Absorption - Beryllium

Procedures for these analyses were developed by the laboratory staff. The procedures for bacteria and chlorine analyses were developed following EPA guidelines. Soil procedures were developed following specifications set forward in "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil," NRC Reg. Guide 4.5. All new procedures and changes to existing procedures must be thoroughly tested, documented, and be approved in writing by the Manager of HS&EL before being implemented. Environmental Analysis is notified of any major changes that could affect analytical results. All procedures are reviewed annually for consistency with state-of-the-art techniques, or at any time an analytical problem is suspected.

Copies of all procedures are kept on file in the office of the Manager of HS&EL.

The following is a general outline of the analytical procedures followed by the laboratories:

Samples received for gross alpha and gross beta screening are counted approximately 24 and 48 hours after collection. Samples exceeding the limits set by Environmental Analysis are recounted 72 hours after collection.

Water samples scheduled for gamma spectral analysis are poured into one-liter Marinelli® containers and are sealed before delivery to the gamma counting area. Routine water samples are counted for approximately eight hours. Samples requiring a lower detection limit are counted from 16 to 72 hours.

Soil samples scheduled for gamma spectral analysis are dried, sieved through a 10-mesh sieve, weighed, and the fine portion is ball-milled. The fine portion is then placed in a 500-milliliter Marinelli container and counted for at least 16 hours.

Filter samples scheduled for gamma analysis are placed in petri dishes and counted for approximately 16 hours.

All samples scheduled for alpha spectral analysis are analyzed in a similar manner regardless of matrix. Prior to dissolution, a known quantity of nonindigenous radioactive tracer is added to each sample. The tracer is used to determine the chemical recovery for the analysis. Tracers used include Pu-236, Pu-242, U-232, U-236, Am-243, and Cm-244. The type and activity level of the tracer used depends on the type and projected activity level of the sample to be analyzed.

After samples are dissolved, radioisotopes of concern are separated from each other and from the matrix material by various solvent extraction and ion exchange techniques. The purified radioisotopes are electrodeposited onto stainless steel discs. These discs are alpha counted for a minimum of 16 hours. If a lower minimum detection limit is required, samples may be counted from 72 to 168 hours depending upon the need. Samples that exhibit a chemical recovery of less than 10 percent or greater than 110 percent are automatically scheduled for reanalysis.

Tritium analyses are routinely performed on most environmental water samples as well as stack effluent samples. Five milliliters of the sample are combined with five milliliters of liquid scintillation cocktail mixture. Environmental samples are counted for 20 minutes and stack effluent samples are counted for 4 minutes. All samples are counted at least twice.

The General Laboratory routinely performs the following analyses for environmental monitoring of plant effluent streams, process wastes and soil residues:

1. Dissolved metallic elements, including tests for 31 cations by emission spectroscopic techniques, and 17 elements by atomic absorption techniques (including beryllium in airborne effluent sample filters).

2. Oxygen demand tests, including total organic carbon, dissolved oxygen, chemical oxygen demand, and biological oxygen demand (5-day incubation).

3. Nutrient tests, including free ammonia and amines, ortho and total phosphate phosphorus, nitrite and nitrate anions, Kjeldahl nitrogen, and total nitrogen.

4. Physical tests, including pH, conductivity, color, total dissolved solids, suspended solids, turbidity, and specific gravity.

5. Soap residues (as alkyl sulfonate).

6. Oil and grease residues, by extraction and infrared or gravimetric detection, and by visual observation.

7. Specific chemical species, including total hardness (as calcium carbonate), alkalinity (as hydroxide, bicarbonate, or carbonate), chloride, fluoride, cyanide, sulphate, and hexavalent chromium.

8. Radioactive species, including gross alpha and beta by gas proportional detection; tritium by liquid scintillation detection; radium, cesium-134, and strontium-89 or 90 by gravimetric separation followed by gas proportional detection. Isotopes of plutonium, americium, thorium, uranium, neptunium, and curium are determined by ion exchange and liquid extraction techniques followed by alpha pulse height analysis.

9. Organic toxic species, including Bromacil, Endrin, Lindane, methoxychlor, toxaphene, phenol, polychlorinated-biphenyls, 2,4-D, 2,4,5-TP Silvex, and total organic halogen.

Procedures for these analyses were developed by the General Laboratory professional technical staff. Procedures were adopted from EPA-approved sources or from other recognized authoritative publications where EPA-approved procedures were not available. Laboratory operational procedures are documented in a standard format and are approved by the manager of the Rocky Flats Analytical Laboratories. The procedures are then distributed to a controlled distribution list to assure that proper testing and approval is performed before changes are adopted. The General Laboratory Quality Assurance Plan requires annual review of procedures for consistency with state-of-the-art techniques and compliance of lab practice with written procedures. In addition, a review is performed whenever an analytical problem is indicated.

The following is a general outline of the analysis procedures followed by the General Laboratory:

Liquid samples received for gross alpha and beta screening are evaporated directly onto planchets for gas proportional counting within 24 hours of collection. When activities exceeding action guidelines set by Environmental Analysis (EA) are observed, notification to EA is made, and reanalysis is begun immediately for verification. For some liquids such as machine oils, a specified volume is evaporated and the residue is taken up in dilute nitric acid for deposit onto the counting planchet. An appropriate factor is applied to account for self-absorption effects determined for each sample.

Liquid and solid samples submitted for alpha spectral pulse height analysis are analyzed in a manner similar to procedures followed by HS&EL. Chemical separation of elements is followed by deposition of an organic extract of 2-thenoyltrifluoroacetone (TTA) complex onto a planchet

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for pulse height analysis of the alpha energy spectrum.

Water samples to be tested for chemical and physical parameters are analyzed within 24 hours of collection, or they are preserved by refrigeration, freezing, or addition of a chemical preservative when required. The tests performed include gravimetric, titrametric, colorimetric, chromatographic, or electroanalytic methods, following procedures specified in the 14th edition of Standard Methods for the Examination of Water and Waste Water, EPA-600/4-79-020, or other authoritative publications.

Water samples to be analyzed for dissolved metallic ions are filtered through a 4.5-μm filter and evaporated onto a graphite electrode for emission spectrographic analysis. Selected elements are determined for sample solutions by atomic absorption methods. This occurs after appropriate chemical treatment to prepare the proper analysis matrix.

Organic toxic species are determined by chromatography, following extraction into an appropriate organic solvent or onto a solid resin using flame ionization, electron capture, or ultraviolet detection. Some organics, such as phenol, are determined by developing a chromaphoric complex and measuring light absorption at a specific wavelength with a spectrophotometer. Measuring occurs after extraction into an appropriate solvent phase.

Tritium is determined by intimate mixing of 5 mℓ of aqueous sample (or of water that has equilibrated with the sample for a predetermined time to ensure exchange) with 17 mℓ of scintillation cocktail. The mixture is counted for 20 minutes in a scintillation well, and an appropriate factor is applied to account for measuring quenching effects determined in situ for each sample.

Cesium, radium, and strontium isotopes are chemically separated from the sample matrix using precipitation techniques. The isotopes are either deposited on planchets with a carrier element for alpha or beta gas proportional counting or (for radium-226) counted directly measuring the radon-222 emanation in a scintillation well by using a Lucas gas collection cell.

APPENDIX D
DETECTION LIMITS AND ERROR TERM PROPAGATION

The Rocky Flats Health, Safety and Environmental Laboratories (HS&EL) have adopted the following definition for detection limit, as given by Harley.[21]

> "The smallest amount of sample activity using a given measurement process (i.e. chemical procedure and detector) that will yield a net count for which there is confidence at a predetermined level that activity is present."

Making a reasonable estimate of the Minimum Detectable Activity (MDA) for a given radiochemical and counting procedure is complicated by the need to consider each of the following:

1. Detector background
2. Detector counting efficiency
3. Count time
4. Sample volume
5. Analytical blank
6. Type and amount of error allowable
7. Chemical yield or recovery for all steps within the process

During 1980, several significant changes took place in the manner in which the HS&EL calculated MDA. The changes were made to more realistically represent the sensitivity of the various analyses. These changes increased the calculated MDA reported by the laboratories; however, the increased MDA does not indicate an increase in the activity level of the samples analyzed.

Because of the low activity of samples analyzed by the HS&EL, negative results are occasionally reported. This is to be expected of samples that have activity levels below their calculated MDA values, especially as the true activity present approaches zero. The primary cause for negative values is low count rate. When a sample in this count range is analyzed, the sample may have fewer counts than the average blank for the sample and analysis type. Another possibility is that the sample may have the same or fewer counts than the background value for the detector upon which the sample is counted.

Table D-1 shows the various formulae used for alpha data reduction during 1981.

Table D-2 shows the typical MDA values for the various analyses performed by the HS&EL and by the General Laboratories. These values are based on an average sample volume, typical detector efficiency, detector background, count time, and chemical recovery. MDA values calculated for individual analyses may vary significantly depending on actual sample volume, chemical recovery, and analytical blank used.

TABLE D-1. Formulae for Activity and Uncertainty Calculations for the Alpha Spectral Analysis Systems

Non-Blank Corrected Sample Uncertainty

$$a_{si} = \frac{1.96\, A_{si}}{V \cdot 2.22} \left[\frac{\frac{C_{si}}{T_s^2} + \frac{C_{Bi}}{T_B^2}}{\left(\frac{C_{si}}{T_s} - \frac{C_{Bi}}{T_B}\right)^2} + \frac{\frac{C_{sj}}{T_s^2} + \frac{C_{Bj}}{T_B^2}}{\left(\frac{C_{sj}}{T_s} - \frac{C_{Bj}}{T_B}\right)^2} \right]^{1/2}$$

Blank Corrected Sample Uncertainty

$$b_{si} = (a_{si}^2 + a_{ri}^2)^{1/2}$$

Non-Blank Corrected Sample Activity

$$A_{si} = \left[\frac{\frac{C_{si}}{T_s} - \frac{C_{Bi}}{T_B}}{\frac{C_{sj}}{T_s} - \frac{C_{Bj}}{T_B}} \right] \cdot \frac{D_{sj}}{V \cdot 2.22}$$

Blank Corrected Sample Activity

$$B_{si} = A_{si} - A_{ri}$$

Minimum Detectable Activity Calculation

Before June 1980

$$L_{si} = \frac{3.29}{E_s \cdot V \cdot 2.22} \left[\frac{C_{Bi}}{T_s\, T_B} + \left(\frac{a_{ri} \cdot E_s}{1.96}\right)^2 \right]^{1/2}$$

Minimum Detectable Activity Calculation

After June 1980

$$L_{si} = \frac{4.66}{Y \cdot E_s \cdot V \cdot 2.22} \left[\frac{C_{Bi}}{T_s\, T_B} + \left(\frac{a_{ri} \cdot E_s}{1.96}\right)^2 \right]^{1/2}$$

(continued)

TABLE D-1. (Concluded)

Legend

A_{ri}	=	Non-blank corrected activity of laboratory reagent blank for isotope i, expressed as picocuries per unit volume.
a_{ri}	=	Non-blank corrected uncertainty of laboratory reagent blank, expressed as picocurie per unit volume.
A_{si}	=	Sample activity for isotope i, expressed as picocurie per unit volume.
a_{si}	=	95 percent confidence level uncertainty of a sample, expressed as picocurie per unit volume.
B_{si}	=	Blank corrected sample activity for isotope i, expressed as picocurie per unit volume.
b_{si}	=	Blank corrected sample uncertainty, expressed as picocurie per unit volume.
C_{Bi}	=	Detector background gross counts for isotope i.
C_{Bj}	=	Detector background gross counts for internal standard isotope j.
C_{si}	=	Sample gross counts for isotope i.
C_{sj}	=	Sample gross counts for internal standard isotope j.
D_{sj}	=	Activity (disintegrations per minute) of internal standard isotope j added to sample.
E_s	=	Absolute detection efficiency for sample detector.
L_{si}	=	Sample minimum detectable activity (MDA) for isotope i, expressed as picocurie per unit volume.
T_B	=	Detector background count time expressed in minutes.
T_s	=	Sample count time expressed in minutes.
V	=	Sample unit volume or sample unit weight.
Y	=	Chemical recovery for sample.

TABLE D-2. Detection Limits for Radioactive and Nonradioactive Materials

Legend

µCi	= microcuries	pCi	= picocuries
µg	= micrograms	mg/ℓ	= milligrams per liter
m^3	= cubic meters	SU	= standard units
mℓ	= milliliters	NTU	= Nepholometer turbidity units

Parameter	Approximate Detection Limit (per sample)	Approximate Sample Volume Analyzed[a]	Approximate Minimum Detectable Concentration
Airborne Effluent Samples			
Plutonium-239, -240	1.0×10^{-7} µCi	3,200 m^3[b]	0.03×10^{-15} µCi/mℓ
Uranium-233, -234, -238	2.0×10^{-7} µCi	3,200 m^3[b]	0.06×10^{-15} µCi/mℓ
Tritium	5.0×10^{-6} µCi	0.06 m^3	$83{,}000 \times 10^{-15}$ µCi/mℓ
Beryllium	1.0×10^{-3} µg	128 m^3[b]	8×10^{-6} µg/m^3
Ambient Air Samples			
Plutonium-239, -240	1.0×10^{-7} µCi	20,000 m^3[c]	0.005×10^{-15} µCi/mℓ
Soil Samples (Radioactive)			
Plutonium-239, -240	1.0×10^{-7} µCi	10 g	10.0×10^{-9} µCi/g
Effluent Water Samples (Radioactive)			
Plutonium-239, -240	1.0×10^{-7} µCi	5,000 mℓ	0.02×10^{-9} µCi/mℓ[c]
Uranium-233, -234, -238	2.0×10^{-7} µCi	1,000 mℓ	0.2×10^{-9} µCi/mℓ
Americium-241	1.0×10^{-7} µCi	5,000 mℓ	0.02×10^{-9} µCi/mℓ[c]
Tritium	2.5×10^{-6} µCi	5 mℓ	500×10^{-9} µCi/mℓ
Effluent Water Samples (Nonradioactive)			
pH		Not Applicable	0-14
Nitrate as N		10 mℓ	0.3 mg/ℓ
Total Phosphorus		50 mℓ	0.2 mg/ℓ
Biochemical Oxygen Demand, 5-Day		10 mℓ	1.0 mg/ℓ
Suspended Solids		100 mℓ	2.0 mg/ℓ
Total Chromium		5 mℓ	0.05 mg/ℓ
Residual Chlorine		10 mℓ	<0.1 mg/ℓ
Oil and Grease		500 mℓ	0.1 mg/ℓ
Fecal Coliform Count		10-100 mℓ	1 organism/100 mℓ
Turbidity			30 NTU
Color			30 units

a. Volume analyzed is usually an aliquoted fraction of the total sample volume collected.
b. Monthly composite.
c. Two-week composite.

APPENDIX E

REPORTING OF MINIMUM DETECTABLE CONCENTRATION AND ERROR TERMS

Throughout the section entitled "Monitoring Data: Collection, Analyses, and Evaluation" in this report, some of the concentrations that are measured at or below the minimum detectable concentration (MDC) are assigned the MDC value. The less-than symbol (<) indicates MDC values and calculated values that include one or more MDC's.

The plutonium, uranium, americium, and beryllium measured concentrations are reported. These reported concentrations include values that are less than the corresponding calculated MDC's and, in some cases, values less than zero. Negative values result when the measured value for a laboratory reagent blank is subtracted from an analytical result that was measured as a smaller value than the reagent blank.

Error terms in the form of a ± b are included with some of the data. For a single sample, "a" is the reagent-blank corrected value; for multiple samples it represents the average value (arithmetic mean). The error term "b" accounts for the propagated statistical counting uncertainty for the sample and the associated reagent blanks at the 95 percent confidence level. These error terms represent a minimum estimate of error for the data. Other analytical and sampling errors are being investigated for future incorporation into an all-inclusive error term for each value.

Ninety-five percent confidence limits for the plutonium concentrations in ambient air have been derived using Fieller's Theorem.[22] These limits consist of a Lower Confidence Limit (LCL) and an Upper Confidence Limit (UCL) on each point estimate for the various concentrations. The calculation of the limits requires knowledge of the analytical error term "b", as described above, and the variance of the air volume measurement associated with a specific sample. These variances are calculated from the data reported as part of a routine flow measurement calibration program for ambient air samplers. Bias errors and temperature coefficients of the sampler readout devices are also statistically computed, and the individual readout devices are individually corrected for those factors.

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